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Evaluating Signalized Roundabout Timing Performance: A Critic Method

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Abstract

Traffic signals are the most widely used form of control for urban intersections, serving not only to regulate the right-of-way and protect conflicting vehicle movements, but also to allocate green time, phases, and cycle lengths that influence overall traffic performance. Variations in signal timing directly affect vehicle delay, queue formation, and efficiency at intersections. In this study, the performance of the selected intersection was first examined under the existing signal timing plan. Four alternative signal timing scenarios were then developed and modelled using microscopic simulation to identify potential improvements. Intersection performance was evaluated based on five key operational indicators: queue length, average delay, number of stops, carbon monoxide (CO) emissions, and fuel consumption. The outcomes of each scenario were subsequently analysed using the CRITIC method to provide an objective ranking. Results revealed that all proposed scenarios improved the level of service (LOS) compared with the base case, with Scenario 2 emerging as the most effective alternative.

Keywords: CRITIC method, Signalized intersection, VISSIM, delay, emission, fuel consumption.

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1. Introduction

Jordan's population has grown substantially over the past two decades, rising from 4.857 million in 2000 to 11.057 million by the end of 2021 ((Department of Statistics, 2015). Amman, the capital city, accounts for nearly 37% of this total population, placing significant pressure on its urban infrastructure. The rapid increase in residents and vehicles has strained the city's road network, leading to recurring congestion, particularly during peak hours. To accommodate rising traffic demand, the Greater Amman Municipality has undertaken several infrastructure modifications aimed at improving mobility and efficiency. Among these initiatives, the Eighth intersection was upgraded by converting its control system from yield-based roundabout management to a signalized intersection, accompanied by adjustments to its geometric design. The details of these modifications are elaborated in the methodology section.

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Signalized intersections are among the most common methods of traffic control in urban areas. Traffic signals ensure the right of way for vehicles, manage conflicting movements, and generally provide higher intersection capacity compared with other control types. However, the efficiency of such intersections is strongly influenced by road topology, as geometry and design directly affect vehicle delays and the extent of congestion during incidents (Al-Dabbagh et al., 2018). One of the most effective strategies to mitigate congestion is the adjustment of signal timings, which can redistribute green time and cycle phases to balance conflicting traffic flows. This approach enables vehicles to pass smoothly through the intersection and significantly reduces delays under certain traffic conditions (Li et al., 2020; Zhou et al., 2022).

A wide range of studies has evaluated intersection performance using different methods and software tools. Mokhtarian et al. (2010) compared roundabout and signalized intersection designs using SIDRA, while (Owais et al., 2020) examined the circumstances under which signalized intersections outperform roundabouts, employing both Synchro and SIDRA. Similarly, (Yulianto et al., 2018) compared the Highway Capacity Manual (HCM) 1997 method with PTV VISTRO to validate intersection performance outcomes. More complex multi-criteria evaluations have also been conducted. For example, (Bayrak & Bayata, 2020) assessed three alternatives signal timing changes, roundabouts, and grade-separated intersections using VISSIM in conjunction with the Analytic Hierarchy Process (AHP). While their results showed that grade separation yielded the highest operational benefits, the costs were prohibitive; the roundabout was deemed more feasible, and signal timing adjustments, despite sometimes increasing delay, were considered the most comfortable solution for drivers.

As traffic volumes continue to rise, conventional intersections risk oversaturation, necessitating more innovative approaches. Research on unconventional intersection designs has demonstrated significant potential to improve both operational and safety performance (Autey et al., 2013; El Esawey & Sayed, 2013). Hadidi et al. (2022) further confirmed that unconventional layouts can substantially reduce traffic delays under heavy demand. Beyond operational efficiency, traffic management also has important environmental consequences. Transportation accounted for 37% of CO_2 emissions from fossil fuel use in 2019, with personal vehicles responsible for nearly 40.5% of this share (Environmental Protection Agency, 2019). In 2020, the transportation sector consumed 26% of total U.S. energy, with 57% attributed to passenger vehicles and light trucks (Davis & Boundy, 2021). Studies using VISSIM have shown that appropriate signal timing can reduce both fuel consumption and emissions (Kutlimuratov et al., 2021; Kwak et al., 2012). Broader sustainability analyses also suggest that transport mode choice is crucial, with Bus Rapid Transit achieving the highest sustainability index and hybrid electric vehicles outperforming other passenger vehicles (Mitropoulos & Prevedouros, 2016).

In addition to infrastructure and signal optimization, some researchers have approached congestion management through demand-side interventions. Guzman et al. (2020), for example, investigated workplace mobility plans as a tool to reduce peak-hour traffic, highlighting strategies such as increased parking fees, carpooling incentives, and the promotion of bicycles and public transit. These findings suggest that a combination of operational improvements, sustainable transport adoption, and policy-driven demand management is essential for addressing congestion challenges in growing urban centres.

When multiple solutions are proposed for a given problem, it becomes essential to evaluate and prioritize them in order to identify the most effective alternative. Multi-

Criteria Decision Making (MCDM) provides a rigorous and practical framework for such evaluations, as it allows decision-makers to assign weights to multiple performance indices and assess their combined influence (Kumar et al., 2017). Within MCDM, determining the relative importance of indices is a critical step, and several methods have been developed to achieve this. Among the most notable are the entropy method and the CRITIC (Criteria Importance Through Intercriteria Correlation) method. The entropy method, while straightforward and widely applied in intersection performance studies (Shao et al., 2019), does not account for the interdependence among indices and is therefore limited in scope. By contrast, the CRITIC method considers both the variability (contrast intensity) and intercorrelation (conflict) of indices, thereby providing a more comprehensive and objective weighting approach (Diakoulaki et al., 1995).

In recent years, MCDM techniques—particularly the CRITIC method have been increasingly applied in the transportation sector. For example, (Camargo Pérez et al., 2015) documented the growing reliance on multi-criteria frameworks in transport studies, while (Pan et al., 2021) applied CRITIC to evaluate the operational performance of unconventional intersections under different traffic volumes. Similarly, (Wu et al., 2020) utilized CRITIC to assess urban rail transit safety. Building on this foundation, the present study applies the CRITIC method to analyse the performance of the Eighth intersection under existing and modified signal timing scenarios. Five operational parameters—queue length, average delay, number of stops, CO emissions, and fuel consumption—were selected to comprehensively evaluate intersection efficiency and sustainability.

2. Methodology

2.1 Study area.

The case study focuses on the Eighth intersection, a strategically important node within Amman's arterial road network. This intersection links two major urban corridors, Zahran Street and Al-Bayader Street (serving east–west movements) with King Abdullah II Street, a principal north–south arterial that carries high traffic volumes and connects central Amman with the city's expanding southern and western districts. Because of its location, the intersection functions as both a commuter gateway and a distributor of intra-city traffic, especially during peak travel hours.

In the past, the intersection was operated as a roundabout with yield control. However, as traffic demand surged due to Amman's rapid population growth and increased car ownership, the roundabout design became insufficient, resulting in severe congestion and safety issues. In response, the Greater Amman Municipality converted the intersection into a signalized roundabout, incorporating selective geometric modifications to accommodate higher volumes and reduce conflict points.

The geometric design of the Eighth intersection combines conventional and unconventional elements:

Northbound (NB) and Southbound (SB) approaches are controlled by a single-point signalized intersection due to the presence of an overpass that facilitates uninterrupted through-movements on King Abdullah II Street. These approaches therefore carry the dominant traffic demand and form the backbone of the intersection's operations.

Eastbound (EB) and Westbound (WB) approaches retain elements of the original roundabout geometry, with signal controls installed at the approach ends. These approaches handle comparatively lower volumes but play a critical role in balancing local access with through-traffic.

The resulting hybrid layout creates a complex interaction between arterial flows and local circulation, making it a suitable test case for evaluating signal timing strategies.

Spatially, the intersection is embedded in a mixed-use urban corridor characterized by dense residential neighbourhoods, commercial activities, and institutional facilities. The location to Amman city and the geometric characteristics of the selected case study is presented in Figure 1.

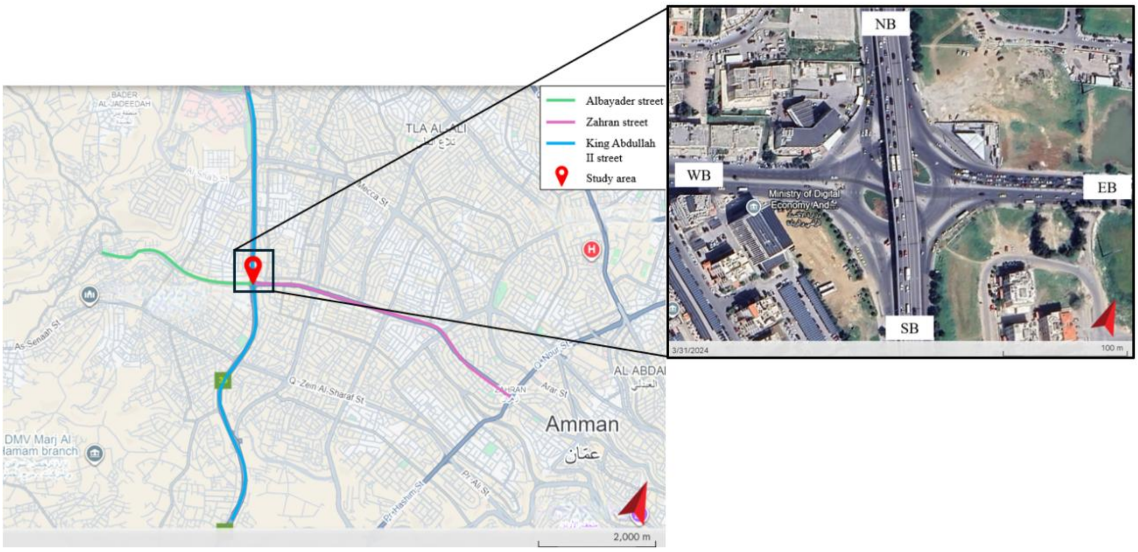

Figure 1: Study “Eighth intersection”. Source : Google Earth.

The Eighth intersection is representative of the challenges faced by many growing cities in the Middle East: a legacy of roundabout-based traffic management combined with rising motorization and limited roadway expansion opportunities. Its hybrid geometry and location at the confluence of major arterials make it an ideal pilot site for testing advanced signal optimization strategies, as improvements here can yield both localized benefits (shorter queues, reduced delays) and network-wide impacts (smoother traffic along King Abdullah II Street and Zahran Street corridors).

The CRITIC method is based on determining objective weights for evaluation indices by considering two fundamental concepts: contrast intensity and conflict (Diakoulaki et al., 1995). Contrast intensity reflects the variability of an index, measured through its standard deviation across different scenarios. A higher standard deviation indicates greater disparity in values, suggesting that the index provides more discriminative information and should therefore be given greater weight. The second concept, conflict, accounts for the degree of interdependence among indices. Strong positive correlations between indices indicate limited conflict, whereas weak or negative correlations suggest higher conflict and greater informational value.

By simultaneously incorporating both variability and correlation, the CRITIC method offers a more comprehensive and objective weighting process than approaches based solely on numerical values. This ensures that the inherent characteristics of the data are fully captured in the evaluation, rather than relying only on raw performance outcomes. In this study, the CRITIC method is employed to assess the relative importance of five key indices vehicle delay, number of stops, queue length, CO emissions, and fuel consumption providing a scientifically robust framework for comparing alternative signal timing scenarios.

2.2 CRITIC method.

The simulations were conducted for five distinct signal timing scenarios, each evaluated using five performance indices. As a result, every scenario produced its own set of simulation outcomes for comparison. To objectively assess and rank these outcomes, the CRITIC method was applied. As described by (Diakoulaki et al., 1995) and further elaborated by (Alinezhad & Khalili, 2019), the CRITIC method provides a systematic framework for assigning weights to indices by considering both their variability and interdependence. The key analytical steps of this approach are outlined below:

Step 1 Construction of the Performance Matrix: the first step involves constructing the performance matrix $\mathbf{A_i}$, as shown in Equation (1). This matrix compiles the simulation results for each scenario across all selected performance indices:

$$\mathrm{A_i} = \left\{\mathrm{Q_i}, \mathrm{D_i}, \mathrm{S_i}, \mathrm{E_i}, \mathrm{F_i}\right\} \tag{1}$$

where:

i: denotes the scenario number $(\mathrm{i} = 1,2,3,4,5)$,
$\mathrm{Q_i}$: represents the average queue length,
$\mathrm{D_i}$: is the average vehicle delay,
$\mathrm{S_i}$: is the number of stops,
$\mathrm{E_i}$: refers to carbon monoxide (CO) emissions, and
$\mathrm{F_i}$: indicates fuel consumption.

Step 2 Formation of the Aggregate Matrix: for each of the five scenarios, an individual performance matrix A_1, A_2, A_3, A_4, and A_5 is constructed to summarize the simulation outcomes. These scenario-specific matrices can then be consolidated into a single aggregate matrix X, as shown in Equation (2). This matrix has dimensions 5×5, where each row corresponds to one scenario and each column represents one of the five performance indices. This aggregate matrix serves as the foundation for applying the CRITIC method, through which the relative weights of each index can be calculated based on their variability and intercorrelation.

$$\mathrm{X} = \left\{\begin{matrix} \mathrm{Q_1}, \mathrm{D_1}, \mathrm{S_1}, \mathrm{E_1}, \mathrm{F_1} \\ \mathrm{Q_2}, \mathrm{D_2}, \mathrm{S_2}, \mathrm{E_2}, \mathrm{F_2} \\ \mathrm{Q_3}, \mathrm{D_3}, \mathrm{S_3}, \mathrm{E_3}, \mathrm{F_3} \\ \mathrm{Q_4}, \mathrm{D_4}, \mathrm{S_4}, \mathrm{E_4}, \mathrm{F_4} \\ \mathrm{Q_5}, \mathrm{D_5}, \mathrm{S_5}, \mathrm{E_5}, \mathrm{F_5} \end{matrix}\right\} \tag{2}$$

Step 3: Normalization of Indices: to proceed with the CRITIC method, each element in the aggregate matrix $\boldsymbol{X}$ is represented by $\boldsymbol{y_{ij}}$, where:

$\mathbf{i}$: denotes the scenario number $(\mathbf{i} = \mathbf{1}, \mathbf{2}, \dots, \mathbf{n})$,

j: denotes the performance index $(\mathrm{j} = 1,2, \dots, \mathrm{m})$,
n: is the total number of scenarios, and
m: is the total number of indices.

Since the selected indices have different measurement scales, normalization is required to transform them into a consistent, dimensionless form. The first step involves adjusting the raw values according to Equation (3). Then the various indexes have distinct scales that must be transformed into a consistent scale for comparison. They must be normalized as in (4):

$$y_j' = \left\{ \begin{matrix} \max\left(y_{1j}, y_{2j}, y_{3j}, y_{4j}, y_{5j}\right) - y_{1j} \\ \max\left(y_{1j}, y_{2j}, y_{3j}, y_{4j}, y_{5j}\right) - y_{2j} \\ \max\left(y_{1j}, y_{2j}, y_{3j}, y_{4j}, y_{5j}\right) - y_{3j} \\ \max\left(y_{1j}, y_{2j}, y_{3j}, y_{4j}, y_{5j}\right) - y_{4j} \\ \max\left(y_{1j}, y_{2j}, y_{3j}, y_{4j}, y_{5j}\right) - y_{5j} \end{matrix} \right\} \qquad (3)$$

$$y_{ij}'' = \frac{y_{ij}' - \min\left(y_{1j}', \ldots, y_{5j}'\right)}{\max\left(y_{1j}', \ldots, y_{5j}'\right) - \min\left(y_{1j}', \ldots, y_{5j}'\right)} \qquad (4)$$

Step 4 Calculation of Variability: After normalization, the variability of each index is determined by calculating the standard deviation, as expressed in Equation (5):

$$S_j = \sqrt{\frac{\sum_{i=1}^{n} (y_{ij}'' - \bar{y_j''})^2}{n - 1}} \qquad (5)$$

where S_j represents the variability of index j, and $\bar{y_j}''$ is the mean of the normalized values for index j. A higher standard deviation indicates greater discriminative power of that index across scenarios.

Because the selected indices are measured on different scales (e.g., queue length in meters, delay in seconds, fuel in litres), they must be transformed into a consistent dimensionless scale to allow for meaningful comparison. The normalization process is carried out in two stages.

First, each raw value y_{ij} is adjusted relative to the maximum observed value of the corresponding index across all scenarios, as shown in Equation (3). Next, the adjusted values are rescaled using the min–max normalization, as expressed in Equation (4). This two-step process ensures that all indices are directly comparable and dimensionless.

Once normalized, the variability of each index is assessed using the standard deviation across scenarios, as defined in Equation (5).

In the CRITIC method, the standard deviation S_j is used to quantify the degree of variation in each index across the scenarios. A higher standard deviation indicates greater differentiation among the alternatives, which implies that the index provides more useful information and should therefore be assigned a higher relative importance.

After measuring variability, the conflict among indices is assessed through pairwise correlations. A symmetric correlation matrix of dimension $m \times m$ is constructed, where each element r_{jk} represents the linear correlation coefficient between index vectors x_j and x_k. The conflict measure for each index j is then computed as:

$$\mathrm{R_j} = \sum_{\mathrm{k}=1}^{\mathrm{m}} (1 - \mathrm{r_{jk}}) \tag{6}$$

Here, indices that are less correlated with others yield higher $R_j$values, signifying their unique contribution to the overall evaluation.

The information content of each index is then derived by combining its variability and conflict measures, as shown in Equation (7):

$$\mathrm{C_j} = \mathrm{S_j} \times \mathrm{R_j} \tag{7}$$

Finally, the objective weight of each index is obtained as in Equation (8) by normalizing the information content values across all indices, ensuring comparability and that the sum of weights equals one:

$$\mathrm{w_j} = \frac{\mathrm{C_j}}{\sum_{\mathrm{k}=1}^{\mathrm{m}} \mathrm{C_k}} \tag{8}$$

2.3 Evaluation of solutions.

Once the objective weights of the indices have been determined, each scenario can be comprehensively evaluated. The process begins by calculating the normalized ratio of the i-th scenario's performance relative to the total across all scenarios for each index, as shown in Equation (9). Next, the weighted score of each scenario with respect to index $j$is obtained by multiplying the ratio $p_{ij}$by the objective weight w_j, as given in Equation (10). Finally, the overall score of scenario i is determined by summing the weighted contributions of all indices, as expressed in Equation (11). This comprehensive score $z_i$represents the relative performance of each scenario. The scenario with the highest score is considered the optimal solution under the CRITIC evaluation framework.

$$p_{ij} = \frac{y''_{ij}}{\sum_{i=1}^{n} y''_{ij}}, j = 1\ to\ 5 \tag{9}$$

$$\mathrm{z_{ij}} = \mathrm{w_j} \times \mathrm{p_{ij}}, \mathrm{i} = 1 \text{ to } 5, \mathrm{j} = 1 \text{ to } 5 \tag{10}$$

$$\mathrm{z_i} = \sum_{\mathrm{i}=1}^{7} \mathrm{z_{ij}}, \mathrm{i} = 1 \text{ to } 5, \mathrm{j} = 1 \text{ to } 5 \tag{11}$$

2.4 Data collection and proposed scenarios

The traffic data used in this study was provided by the Greater Amman Municipality (GAM) and obtained from inductive loop detectors installed at the study location. Data collection was conducted during the PM peak hour, representing the highest traffic demand period of the day, and took place in August 2021 to minimize the influence of COVID-19-related travel restrictions. The results indicated that the northbound (NB) and southbound (SB) traffic volumes were approximately equal, with the NB–SB corridor carrying higher demand than the eastbound–westbound (EB–WB) approaches, thereby designating it as the primary traffic stream. U-turn movements were generally minor across all approaches. Additionally, the proportions of turning movements varied between opposing directions, reflecting asymmetrical flow patterns. A detailed breakdown of the intersection counts is presented in Table 1.

Table 1: Data from detectors during peak hour

Approach	*Movement*	*Cars*	*Heavy Vehicles*	*Total Volume per Approach*
Northbound	Left Turn	965	212	1579
	Right Turn	137	30	
	U-Turn	193	42	
Southbound	Left Turn	519	92	1540
	Right Turn	675	119	
	U-Turn	116	20	
Eastbound	Left Turn	533	101	1720
	Right Turn	274	52	
	Through	604	115	
	U-Turn	34	7	
Westbound	Left Turn	170	28	1099
	Right Turn	126	21	
	Through	569	93	
	U-Turn	79	13	

Data provided by Greater Amman Municipality.

3. Simulation results

As noted earlier, five performance indices were used to evaluate the intersection. These indices were applied first to the current signal timing plan (Scenario 1), implemented by the Greater Amman Municipality, and then to four alternative scenarios designed to enhance intersection performance.

The four proposed scenarios differ from Scenario 1 primarily in two aspects:

I. Cycle length and lost time: The cycle length was increased from 180 seconds to 200 seconds, while the lost time was reduced from 15 seconds to 12 seconds per cycle.
II. Allocation of green time: The green time for each phase was adjusted based on the ratio of the dominant movement’s traffic volume to the total volume for that phase. This proportional allocation ensures that movements with higher demand receive a greater share of green time. This adjustment formed the basis of Scenario 2.

Building on Scenario 2, Scenarios 3, 4, and 5 further modified the timing structure. A third conceptual adjustment was introduced by altering the signal phasing scheme. In Scenario 1, the 180-second cycle was divided into three phases:

Phase 1: Southbound–Northbound (SB–NB) movements,
Phase 2: Eastbound (EB),
Phase 3: Westbound (WB).

In contrast, the proposed scenarios maintained the SB–NB movement as the first phase but restructured the EB–WB operations:

Phase 2: EB–WB left turns,
Phase 3: EB–WB through movements.

The detailed timing parameters for all scenarios are presented in Table 2.

Table 2: Scenarios' timing for signal details

		Time (sec) for each scenario				
	Signal Time Details	*Scenario 1*	*Scenario 2*	*Scenario 3*	*Scenario 4*	*Scenario 5*
Currently used scenario	Cycle Length	180				
	Lost Time	15				
	EB Phase	60				
	WB Phase	70				
	SB-NB Phase	35				
Proposed scenarios	Cycle Length		200	200	200	200
	Lost Time		12	12	12	12
	EB-WB LT Phase		53	65	65	57
	EB-WB TH Phase		47	51	60	51
	SB-NB Phase		88	72	63	80

The analysis revealed that the proposed scenarios achieved measurable improvements across the five performance indices: queue length, vehicle delay, number of stops, CO emissions, and fuel consumption, though the magnitude of improvement varied among scenarios (see Table 3). Importantly, these modifications led to a notable enhancement in the intersection's Level of Service (LOS). Under the existing timing plan (Scenario 1), the LOS was rated F, indicating oversaturation and severe congestion. By contrast, Scenarios 2, 3, and 5 elevated the LOS to D, reflecting acceptable performance under high-volume conditions, while Scenario 4 produced an LOS of E (*Highway Capacity Manual*, 2000).

To systematically evaluate and compare the relative effectiveness of these scenarios, the CRITIC method is applied in the following section (Section 4). This method assigns each scenario a weighted score (out of 100), enabling the identification of the optimal timing plan based on a balanced consideration of all performance indices.

Table 3: Simulation results using VISSIM

Scenarios	*Queue length*	*Average vehicle delay*	*Number of STOPS*	*CO Emission*	*Fuel consumption*	*LOS*
Scenario 1	54.25	92.29	4.29	2362.01	33.79	F
Scenario 2	31.6	44.75	1.62	1244.74	17.81	D
Scenario 3	32.58	52.11	2.1	1434.39	20.52	D
Scenario 4	34.16	57.51	2.17	1436.58	20.55	E

Scenario 5	32.02	47.99	1.75	1296.79	18.55	D

4. Analysis of the results using CRITIC method

Figure 2 presents the scores of the five scenarios based on the CRITIC analysis. Among the alternatives, Scenario 2 achieved the highest score at 27.4%, indicating that it is the most suitable option for operating the intersection under the prevailing traffic volumes and existing geometric constraints. The CRITIC method produces relative scores among competing scenarios, meaning that the ranking reflects comparative rather than absolute performance. Consequently, if a scenario performs the worst across all indices, it receives a score of zero, as defined in Equation (3). This explains the outcome for Scenario 1, which consistently exhibited the poorest performance and was therefore assigned a score of zero.

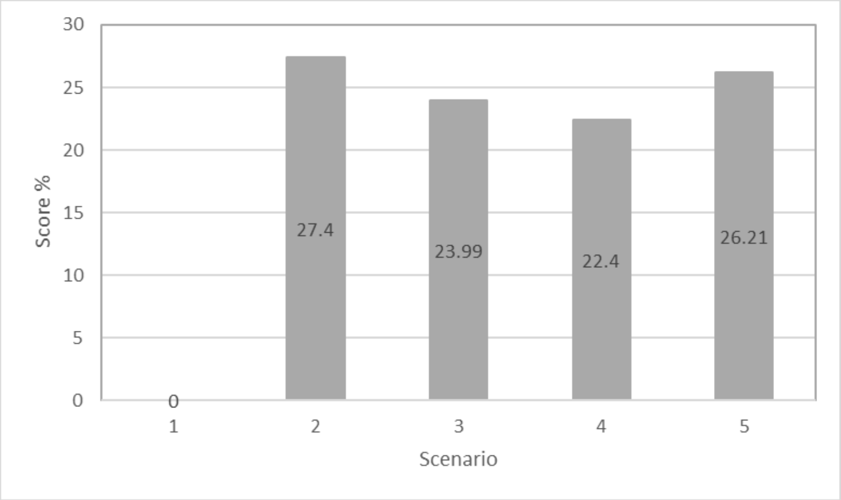

Figure 2: Scores for each scenario using the CRITIC method

5. Discussion

Signalized intersections are among the most widely used methods of traffic management, as they guarantee the right of way for conflicting vehicle movements and generally provide higher capacity compared to other control types. In this study, the CRITIC method was applied to evaluate the performance of a signalized roundabout under five timing scenarios, including the existing control plan and four proposed alternatives. The results demonstrated that the proposed modifications improved the Level of Service (LOS) and yielded substantial performance gains across key operational and environmental indices. Notably, the CRITIC analysis revealed that the score increased from 0% for the current situation (Scenario 1) to 27% for Scenario 2, which emerged as the most effective alternative under the prevailing traffic conditions.

Previous studies have shown that adjusting intersection signal timing can effectively alleviate congestion and improve traffic flow (Li et al., 2020). In this research, modifications to cycle length, lost time, and phase allocation were iteratively tested, resulting in an improvement in the Level of Service (LOS) from F to D. Such improvements allow vehicles to pass more smoothly through the intersection, consistent with findings by (Zhou et al., 2022), who reported that under certain traffic flow conditions, optimized signal timing reduces intersection congestion. Furthermore, enhanced LOS is directly associated with smoother operations, particularly through improved queue management. The reductions in queue length observed in Scenarios 2 and 5 reinforce the results of (Abutahoun et al., 2025), who demonstrated that accurate queue length estimation through simulation is critical for optimizing intersection performance and minimizing the risk of gridlock.

Previous studies have demonstrated the influence of signal timing on fuel consumption and vehicle emissions (Kwak et al., 2012). The findings of this research confirm these results, showing significant improvements when both cycle length and green time were adjusted. In the proposed scenarios (2, 3, 4, and 5), the cycle length was standardized at 200 seconds, which was shorter than the actual cycle length in Scenario 1. This adjustment had a positive effect, reducing both fuel consumption and emissions by nearly 50% compared with the base case.

Furthermore, allocating additional green time to the NB–SB direction, which carried higher volumes than the EB–WB approaches, generated substantial operational benefits. These included reductions in queue length, vehicle delay, and number of stops, alongside lower fuel consumption and emissions. Among the alternatives, Scenario 2 achieved the highest performance, with a CRITIC score of 27.4%, highlighting how cycle length optimization and proportional green time allocation can simultaneously improve multiple performance indices.

It should be noted, however, that the reliability of the results is influenced by the quality of the data. The traffic data used in this study was collected via inductive loops at the study site. While useful, such sensors may be subject to errors, and calibration is often necessary to enhance accuracy. Future studies may benefit from integrating remote sensing technologies, such as mobile-based data collection, to validate loop detector outputs. Moreover, the data was collected in August, a summer period when congestion levels are typically lower. For more representative results, similar studies should also be conducted during the fall or spring, when traffic demand is higher due to increased student and faculty presence in the city.

From a methodological perspective, this study demonstrates the value of Multi-Criteria Decision Making (MCDM) approaches in traffic operations research. The CRITIC method, in particular, provides an objective mechanism for assigning weights to evaluation indices by simultaneously accounting for variability and interdependence (Kumar et al., 2017). The results of this study show that, compared to the current situation (Scenario 1), the optimal scenario substantially improves all five performance indices. These findings underscore the practical importance of applying advanced MCDM techniques to guide decision-makers in optimizing traffic signal timing and addressing congestion challenges in urban intersections.

6. Conclusion

The analysis of the Eighth intersection in Amman demonstrates that signal timing adjustments can significantly improve operational efficiency and sustainability outcomes in heavily congested urban environments. Using five performance indicators queue length, vehicle delay, number of stops, CO emissions, and fuel consumption the study shows that even modest changes in cycle length, lost time, and phase allocation can transform intersection performance from a failing level of service (LOS F) to an acceptable operating condition (LOS D). Among the evaluated options, Scenario 2 consistently outperformed all others, achieving the greatest reductions across all critical measures and receiving the highest CRITIC score, thereby underscoring its robustness as the most effective strategy under existing geometric and traffic conditions.

The improvements are not only operational but also environmental. By halving fuel consumption and CO emissions compared to the current baseline, the optimized timing scenarios offer dual benefits for congestion relief and sustainability, aligning with global efforts to reduce transportation-related greenhouse gas emissions. These outcomes reinforce the central role of traffic signal optimization as a cost-effective, immediately implementable solution when compared to high-cost alternatives such as grade separation or full geometric redesign.

Moreover, the study demonstrates the utility of the CRITIC method as an objective multi-criteria decision-making tool for balancing trade-offs between diverse performance indicators. By integrating variability and intercorrelation of indices, the CRITIC approach ensures a scientifically rigorous and transparent evaluation framework that can guide municipal decision-makers in selecting strategies that optimize both efficiency and environmental impact.

Nevertheless, limitations remain. Data collection relied on inductive loop detectors which could have some errors that need to be addressed. In addition, this data was taken during summer season which may not reflect all year-round traffic. Future studies should incorporate multi-seasonal datasets, integrate remote sensing technologies, and explore adaptive or AI-driven traffic control systems that dynamically respond to real-time demand fluctuations. Additionally, expanding the scope to corridor-level or network-wide optimization would provide further insight into cumulative impacts on urban mobility and sustainability.

In conclusion, this research highlights that targeted, data-driven signal timing optimization provides an effective pathway to enhance traffic flow, reduce delays, and minimize environmental costs. By demonstrating the measurable gains of relatively simple operational interventions, it offers both practical guidance for urban traffic management and a foundation for future exploration of adaptive, technology-enabled intersection control strategies.

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