Journal of Engineering and Computer Sciences
Vol. 16, No. 1, pp. 43-58 (Jan 2024)

Left-Turn Geometrical Attributes: A Microsimulation Approach to Signal Optimization

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[Received: 21 January 2025, Revised: 6 April 2025, Accepted: 6 April 2025, Published 11 May 2025]

Abstract: The ordinary signalized intersection geometry and control are facing tremendous traffic challenges. Signal timing control and innovative geometric designs contribute to mitigate congestion at signalized intersections worldwide. The author has investigated a geometric design case in Qassim region, in Saudi Arabia which involves a roundabout intersection. The intersection was recently reconstructed with a new geometric design involving partial Exclusive Left- Turn Bays. The research was aimed to investigate three different geometric designs of a partial exclusive left turns signalized intersection, a roundabout intersection, and a proposed full exclusive left turns signalized intersection. Analyses for the existing case, the roundabout, and the exclusive left turns were coded and validated using microsimulation model (VISSIM) with field collected data from the studied signalized intersection. The results showed that, despite fewer improvements in vehicle delays and queue length (meters) of the proposed full exclusive left turns in the comparison with the existing partial exclusive left turns, the geometry designed with a roundabout case yield shorter queue lengths and vehicle delays than the case of signalized intersections designed with partial or full exclusive left turn bays in certain traffic volume levels.

Keywords: Signalized intersections; optimization; geometric design; driving behavior; traffic efficiency; exclusive left turns.

1. INTRODUCTION

Urban cities are facing several challenges that are related to transportation. To manage urban traffic effectively, livability, safety, and sustainability must be balanced. In the coming decades, cities are expected to grow rapidly, which will make it difficult to manage traffic, as road networks are often limited or nonexistent due to lack of space. It is crucial for assessing the overall impacts of development to understand what demands development will place on the community's transportation network. Whenever a development arises, it is likely to generate traffic, which may cause congestion and oblige the community to invest more in their transportation network, such as by building new roads, improving signage, installing traffic signals, or building roundabouts. Besides causing traffic congestion for users on the road, congestion also contributes to several other problems, such as delayed travel times, air pollution, accidents, and signal failures on major transportation routes. Drivers may switch to another roadway if one becomes congested that was not originally designed to flow through [1]. Therefore, traffic impact analyses are becoming increasingly common as a planning tool to predict future demands on transportation networks as well as mitigate their negative impacts. In a time when budgets are limited for improving public facilities and infrastructure, understanding traffic impacts becomes even more important [2].

There are many intersections in every urban city, each allowing vehicles and pedestrians to cross, turn, and maneuver. Intersections are often equipped with traffic control equipment, such as traffic lights and other traffic management devices, to ensure traffic safety and smooth flow. Innovative geometric designs play a crucial role in improving left-turn flow and optimizing traffic efficiency at signalized intersections. These designs incorporate dedicated left-turn lanes, optimized turning radii, and advanced signal timings that account for both vehicle movement patterns and pedestrian safety. By analyzing traffic dynamics, these modifications help reduce conflict points and minimize delays, which are common sources of congestion. Furthermore, integrating real-time signal adjustments with geometric improvements allows for adaptive traffic management, enhancing throughput during peak hours. This synergy between geometric design and signalization underscores the need for a comprehensive approach to intersection management, leading to improved operational performance and safer conditions for both drivers and pedestrians. Ultimately, combining innovative geometric strategies with advanced signal control can significantly enhance urban traffic systems. In order to improve traffic and ensure traffic safety, road intersections must be designed and managed appropriately. [3].

Like other key regions in Saudi Arabia, Buraidah City also faces similar traffic congestion and long queues during the peak periods. The city consists of several intersections that include signalized intersections and roundabouts. In Buraidah city, specifically at the intersection of King Salman Road and Omar Bin Al Khattab Road, there was a roundabout that caused traffic and led to traffic safety and operations issues. The Municipality of Al-Qassim region applied a new signalized intersection implementing partial Exclusive Left- Turn Bays. Now, the study will investigate two cases studies for the studies intersection. The study aimed to assess the traffic operations for the existing case with partial exclusive left turns, the before case that were designed with a roundabout and future scenario of full exclusive left turns.

Thus, the purpose of this study is to describe, analyze, and evaluate various intersections that exist, along with their merits and demerits. The contribution of this study will be described in the following manner:

1- Assessment of partial Exclusive Left-Turn Bays traffic operations and their effects on the intersection (Base Scenario)
2- Assessment of fully Exclusive Left-Turn Bays traffic operations and their effects on the intersection (Scenario 1)
3- Assessment of the roundabout traffic operations and their effects on the intersection (Scenario 2)

A full exclusive left-turn bay includes a dedicated left-turn lane and a protected signal phase, ensuring high traffic flow efficiency by reducing congestion and minimizing conflicts. However, it requires more space and is best suited for intersections with high left-turn volumes [43,44]. In contrast, a partial exclusive left-turn bay may share a lane with through traffic and typically operates with a permissive or shared signal phase. While it requires less space and works well for moderate left-turn traffic, it may lead to potential conflicts, making it less efficient in handling high volumes [43,44]. Table 1 summarizes the Key Differences Between Full and Partial Exclusive Left-Turn Bays.

Table 1: Key Differences Between Full and Partial Exclusive Left-Turn Bays

Feature	Full Exclusive Left-Turn Bay	Partial Exclusive Left-Turn Bay
Dedicated Left-Turn Lane	Yes	Sometimes (shared with through)
Left-Turn Signal Phase	Protected (separate phase)	Permissive or shared phase
Traffic Flow Efficiency	High (reduces congestion)	Moderate (potential conflicts)
Space Requirement	More space needed	Less space needed
Ideal for High Volumes?	Yes	No, best for moderate left-turn traffic

For well validated and calibrated models, data was collected and analyzed using modern data analytics techniques. Existing conditions were analyzed and based on their results; past and future scenarios were computed for extensive comparative analyses. Detailed conclusions and recommendations were presented at the end of each chapter of the study. The findings from this research study will provide better insight into how different intersection designs affect operational consequences in current traffic control systems. This paper is structured as follows. An overview of the literature regarding different intersection designs is presented in Section 2. Section 3 presents an overview of the study area as well as the intersection selected for analysis. Section 4 details the data collection procedures. Developing and validating the microsimulation model (VISSIM) was described in section 5. Results and discussion of the study were provided in Section 6. Section 7 concluded with a summary of key findings and recommendations for future research.

2. LITERATURE REVIEW

Cities with major intersections often experience oversaturation during peak hours due to traffic bottlenecks. A significant amount of research has been done over the past 50 years to address the problem of oversaturation. Many past studies have discussed these issues of congested and oversaturated signalized intersections [4-6]. Traffic congestion at bottleneck intersections may affect other intersections, causing vehicle queues to spread all over the arterial network, resulting in congested and jammed network [7,8]. Conflicts between left-turn movements and opposite through movements are the main cause of inefficiency at the intersections, with left-turn conflicts significantly impacting traffic capacity, delays, and safety These conflicts are further compounded by the fact that left-turn movements often involve a U-turn, which requires more space than a standard turn. This can lead to traffic congestion and an increased risk of accidents. [8,9]. It is therefore crucial to organize and control the movement of left-turn vehicles and improve the intersection's traffic efficiency.

In order to separate different movements, traffic signal control is highly common. In situations where the traffic volume is low enough to allow left-turning vehicles to clear an intersection safely while leaving an acceptable gap between opposing through vehicles, permissive phasing is an efficient way of controlling left turners in any intersection [10]. However, with increasing traffic volume at an intersection, the gaps between opposing traffic could become critically small, which in turn would delay left-turning vehicles and may also compromise intersection safety [10]. The protected phasing signal strategy is more secure and effective at high-volume intersections. But these conventional protected left turn phases depend upon various criteria such as delays, traffic volume, intersection geometry, crash rates, etc [11]. Most studies involving left turning vehicles focus on safety and conflict rather than traffic efficiency, such as congestion and queues [12-14]. In terms of traffic operations, left turners often contribute to oversaturation because either they require separate green phase allocations, or longer overall phase green times [15-17]. A common practice is to ban and reroute the offending left turning volume to avoid capacity problems [18]. By eliminating left turning vehicles, this strategy enhances intersection capacity but also causes left turning vehicles to make a long detour in the road. Increasing the number of exclusive left-turn lanes per approach at the intersection may alleviate congested conditions and long green time for left turns [19]. A study was conducted to examine how short left-turn bays influence the capacity of through movements under various signal settings. The findings suggest that inadequate left-turn bay lengths can cause spillovers, affecting the efficiency of through lanes [45]. Similarly, research analyzing the effects of varying numbers of exclusive left-turn lanes on intersection performance, using a case study from Qatar, demonstrates that increasing the number of such lanes enhances overall capacity, particularly in high left-turn demand scenarios [46]. Furthermore, a comprehensive review on left-turn lane offsets emphasizes their influence on driver sight distance, safety, and operations, noting that positive offsets contribute to improved safety and operational efficiency at intersections [47].

Signalized intersections enhance traffic flow by systematically organizing vehicle movements and minimizing conflicts, thereby facilitating the efficient movement of multiple traffic streams. When signals are properly timed, they can significantly reduce congestion and delays. One of the recent studies examined the effects of coordinating signal timings on arterial roads. The study showed a 20% reduction in travel time, leading to smoother traffic flow and decreased congestion [48]. Furthermore, signalized intersections allow for priority control of emergency and transit vehicles, improving response times and the efficiency of public transportation. Additionally, adaptive signal systems that adjust to real-time traffic conditions optimize overall performance. Another study related to adaptive controllers evaluated the implementation of Adaptive Signal Control Technologies (ASCT) in urban areas. The findings indicated a 10% reduction in average delays and a 5% improvement in travel time reliability [49]. The high number of conflict points and the severity of crash outcomes underscore the necessity of incorporating mitigation strategies in the design of signalized intersections to enhance safety performance [49].

Signal timings can be inadequately designed, leading to prolonged waiting periods and traffic congestion, particularly when traffic volume is low [50]. Vehicles are required to halt at red lights, even in the absence of other traffic. The installation of traffic signals incurs significant costs, with ongoing maintenance further contributing to expenses. Although traffic signals can reduce severe collisions, they often lead to an increase in rear-end accidents due to sudden stops. One such study examined various design factors that should be considered for optimal safety performance, including lane usage and geometric configurations. In areas with low traffic density, alternative solutions such as stop signs or roundabouts might be more effective [50].

The choice between roundabouts and signalized intersections significantly impacts travel time and overall traffic performance. Roundabouts generally offer higher capacities and reduced delays, particularly in single-lane configurations and under moderate traffic volumes [51]. However, in multi-lane scenarios or areas with heavy traffic, signalized intersections may provide better flow capacities and trip-serving capabilities. Therefore, the decision should be based on specific traffic conditions, intersection design, and urban planning considerations [51].

PTV VISSIM is one of the few simulations software that can be used to model both signalized intersections and unsignalized intersections such as roundabouts [20]. Meanwhile there are many studies around the world evaluating the impact of converting signalized intersections to roundabout. This is since the roundabouts reduce vehicle delays and number of stops despite high volumes because vehicles go slowly in moving queues rather than stopping fully [21]. Like several studies, this study also aims to present a comparison between different signalized intersections layouts and the proposed roundabout at the study location using microsimulation software [22-24].

3. STUDY AREA

The signalized intersection between Omar bin Khattab road and King Salman Road was selected for the data collection and the analysis for this study in the governorate of Buraydah in the Qassim region of Saudi Arabia. It's been reported that during the weekends, the Qassim Traffic Department experiences very high traffic flows as people travel to different cities within and outside of the region for various traveling reasons [25]. With 13 governorates, including Buraydah, the Qassim region is centrally located, connecting many neighboring regions, such as Riyadh, Hail and Madinah. The selected intersection is signalized with a pre-timed controller with 4 phase signal groups. The intersection operates as a through and partial exclusive left turn at the east west approach whereas north south approach operates as an isolated group phases. Areas surrounding the study intersection are residential with restaurants and markets. Restaurants and markets cause a lot of movements in the PM peak hours. High congestion and delays in the intersection were observed in the peak hours. The study intersection comprised of two very important roadways which carries load of vehicle movements through the day. The King Salman Road runs east west side and present between ring road and Al Taraffiyah road. Whereas Omar bin Khattab road runs north south ways and is present between major highways such as King Abdulaziz and Ring Road. Figure 1 shows the study intersection in the Buraydah district of Qassim.

Figure 1: Study intersection

4. DATA COLLECTION AND DESCRIPTION

Various types of data were collected during the data collection process, which consisted of two subtasks i.e. surveillance survey and actual data collection. For collecting data, the study conducted surveillance surveys at various times to observe peak periods and traffic trends for the study location. After initial observations and surveillance, the PM peak period between 5:30 and 6:30 was selected. The location for the video recording was also selected. Once received permission from Al Qassim Traffic Department and Buildings Department, Video camera was placed nearby highest possible building to capture selected field observations such as (a) Signal Timing plans (b) Turning Movement counts (Traffic Flows) (c), A minimum of two queue lengths (meters) at different approaches. A typical camera position can be seen in Figure 2 below, which shows how the camera was positioned. The recordings were performed using high-definition quality video cameras on the weekends during PM peak traffic hours. For purposes of accuracy and efficiency, the videos were slowed down to 0.5 times the speed of the real simulation, and the time of the videos was analyzed up to two decimal points.

Traffic flows (Turning movement counts) were collected for all the approaches during the selected peak period. Total intersection traffic flow was observed around 6,000 vehicles per hour with the highest approaching volume (1750 veh/hr) at the South bound approach of Omar bin Khattab road. Whereas the east bound approach of King Salman had the second highest approach volume of 1359 veh/hr. Queue lengths were observed through each cycle and the maximum queue length in meters was recorded which was later used for the validation of the model. The longest queue length (205 meters) was found at the south bound approach of Omar bin Khattab road while overall total average maximum queue length for the intersection was around 145 meters. Data on traffic signal timings were also collected

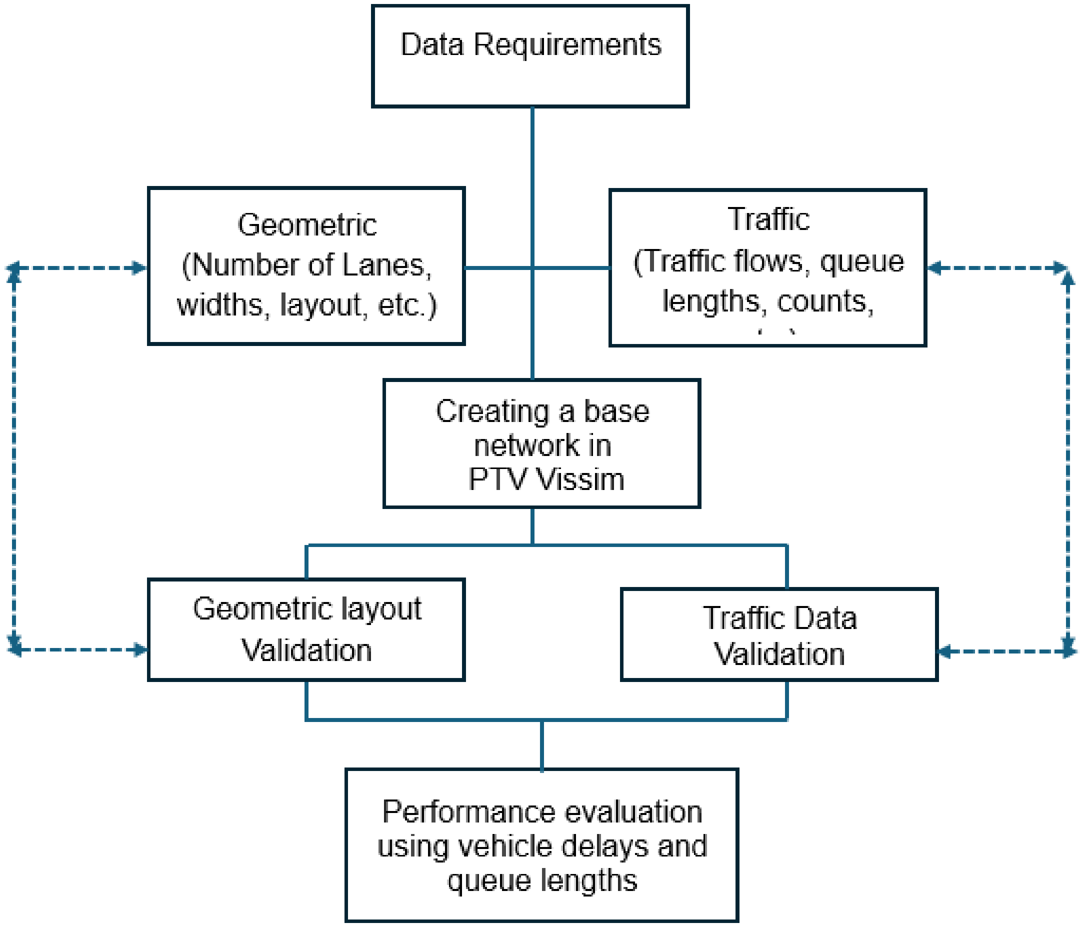
Journal of Engineering and Computer Sciences
Vol. 16, No. 1, pp. 43-58 (Jan 2024)

using both manual observations at the field and from the captured video frames. Finally, maps were taken from Google Earth for the selected intersection to build accurate base network geometries in VISSIM software.

Figure 2: Video Camera position for the field survey

5. METHODOLOGY

The research embodied in this paper presents an approach for the development of microsimulation model to evaluate different design layouts of intersection. The methodology presented is a typical flow diagram showing key steps to achieve the objectives of this present study. Three different scenarios would be developed and then compared to evaluate their results. The methodology approach started with the collection of geometric and traffic data from the field as mentioned in previous sections. Once the data was gathered, base network (Base scenario) was created in PTV VISSIM software. VISSIM is a microsimulation software which is very well recognized throughout the world and can be used to model various transport operations for both signalized and unsignalized intersections [21,24,26]. The factors considered for developing an intersection model in VISSIM were driving behavior, geometric, and traffic representation. This study has used default parameters for the driving behavior whereas geometric and traffic data was collected from the field [27]. This data was used to validate the base model to achieve a well-represented model for further analysis. The evaluation metrics such as vehicle delay (seconds) and queue lengths (meters) were considered to compare these models' performance [22,28,29]. Figure 3 shows the flow diagram for the presented methodology.



6. RESULTS AND DISCUSSION

6.1 Model Validation

During a simulation-based study, it is important to validate the model results by comparing them with field conditions. Since driving behavior varies from place to place, it is imperative to calibrate the model to begin with. Models without validation can provide biased results. Local conditions were considered when calibrating and validating default model parameters using queue lengths and turning volumes [30]. Traffic simulation models can be validated using various performance measures, such as travel time, delay, queue lengths, and turning movement counts at intersections. Most commonly among the mentioned performance indicators for validation include traffic flows (counts or volumes) and queue lengths. Using turning counts and queue lengths to validate microsimulation models is crucial to ensuring their accuracy and reliability and many studies have used these parameters [22,31-33]. By simulating traffic conditions realistically, traffic management, infrastructure planning, and policy implementation can be accomplished with a solid foundation. Thus, traffic simulation models must be continually enhanced and maintained through data collection, model calibration, and iterative validation.

It is critical that the micro-simulation results are compared to field measurements to ensure that no outliners appear in the results. To ensure that the results reported for the model are a true statistical representation of the real world, this study used traffic flows and queue lengths for validating the base scenario. The validation process was conducted based on collected data to closely match traffic counts and queue lengths. Considering the traffic flow, the validation yielded a close match to the turning movement counts captured in the field for various intersections with the percentage difference within the acceptable range of 10% [34,35]. Table 2 presents the validation data for the traffic flows at the study intersection. The difference between the queue lengths in the VISSIM model and the collected queue lengths was less than 10%. Thus, the model can be called a "well represented microsimulation model" [36]. Table 3 summarizes the validation results against queue lengths for the base network which includes queue lengths for all the approaches of the study intersection. The percentage deviation of the queue lengths in the developed microsimulation model is well under the 10% threshold, proving the accuracy and reliability of the model developed.

Table 2: Validation based on traffic flows

Sr No	Movements/Approaches	Volume Model veh/hr	Volume Data veh/hr	%age difference
1	Umar Bin Al Khattab NB	1015	1039	2.31%
2	Umar Bin Al Khattab SB	1144	1219	6.15%
3	King Salman WBT	749	742	-0.94%
4	King Salman EBT	690	716	3.63%
5	King Salman WBL	400	433	7.62%
6	King Salman EBL	481	519	7.32%
	Average Volumes Values veh/hr	**747**	**778**	**4.3%**

Table 3: Validation based on maximum queue lengths

Sr No	Movements	Avg Max Queue Length Model	Avg Max Queue Length Data	%age difference
1	Umar Bin Al Khattab NB	158.32	150	-5.55%
2	Umar Bin Al Khattab SB	205.75	200	-2.88%
3	King Salman WBT	108.62	100	-8.62%
4	King Salman EBT	102.16	95	-7.54%
	Average Queue length Values (meters)	**143.7**	**136.2**	**-6.1%**

6.2 Comparative Analysis

Results illustrate that roundabout (Scenario 2) has a higher capability of vehicle passing than intersections, thus showing higher reductions in vehicle delays and queue lengths than fully exclusive left turn signal (Scenario 1). The results are in line with several pasts studies where results were compared between roundabouts and signalized intersections without considering layout design and relatively moderate traffic flow [37,38]. It is also observed that conversion to fully exclusive lanes (Scenario 1) from partial exclusive left turn bay intersection (Base scenario) yields better results [10,39,40]. Table 4 shows the comparative results among the scenarios showing roundabout causing significant reductions in average vehicle delays. The results show that converting to roundabout intersection from the existing partial exclusive left turns would yield better results in terms of vehicle delays and ultimately Level of services [21]. However, it is important to note that these results are based on the collected field traffic flows and any major variations in the counts may yield different results [38].

Table 4: Average Vehicle delays for the modeled scenarios

MOVEMENT	Base Scenario	Scenario 1 Full exclusive Left turn		Scenario 2 Roundabout	
	Avg Delay (sec)	Avg Delay (sec)	Delay Reduction	Avg Delay (sec)	Delay Reduction
Salman WBT	65.71	58.23	-11%	14.44	-78%
Salman WBL	65.1	53.14	-18%	14.72	-77%
Salman EBT	67.31	59.66	-11%	12.35	-82%
Salman EBL	65.8	55.04	-16%	10.52	-84%
Umar Street SBL	90.29	64.19	-29%	6.87	-92%
Umar Street SBT	90.29	54.67	-23%	6.09	-93%
Umar Street NBL	71.01	64.13	-29%	8.28	-88%
Umar Street NBT	71.01	61.92	-13%	7.63	-89%
Total Intersection Avg Delay (sec)	**69.14**	**58.87**	**-15%**	**10.11**	**-85%**

Like the delays experienced in vehicles, the model setup was also executed to evaluate the outcomes concerning the average maximum queue length across various scenarios. The findings revealed that the average maximum queue length was markedly decreased in the scenario involving a roundabout. This implies that roundabouts have the potential to significantly alleviate congestion and enhance the overall traffic flow in relation to the demand assessed throughout the study. Table 5 shows the comparative results among the modeled scenarios.

Table 5: Average Maximum Queue length for the modeled scenarios

MOVEMENT	Base Scenario	Scenario 1 Full exclusive Left turn		Scenario 2 Roundabout	
	Max QLen (m)	Max QLen (m)	Queue Length Reduction	Max QLen (m)	Queue Length Reduction
Salman WBT	108.62	103.03	-5%	55.90	-49%
Salman WBL	97.01	81.64	-16%	55.90	-42%
Salman EBT	102.16	95.82	-6%	63.69	-38%
Salman EBL	124.25	95.49	-23%	63.69	-49%
Umar Street SBL	205.75	170.52	-17%	32.11	-84%
Umar Street SBT	205.75	96.52	-39%	32.11	-84%
Umar Street NBL	158.32	56.92	-17%	31.55	-80%
Umar Street NBT	158.32	67.68	-57%	31.55	-80%
Total Intersection Avg Delay (sec)	**205.75**	**170.52**	**-17%**	**63.69**	**-69%**

6.3 Statistical Analysis

Due to the stochastic (random) nature of simulation models including VISSIM, a minimum of 10 simulation runs were performed with different random seed numbers to ensure that the values reported are a true statistical representation of the average. As a result, measured data like delay, maximum queue length were recorded and averaged over 10 simulation runs [41]. Given the varying results that inherently exist between microsimulation runs (due to the random seed number), every model is required to evaluate its reported results to ensure that they are representative of the model and not skewed towards a statistical outlier. This is critical since the true average of the model results is unknown. Confidence, as outlined in this section, was intended to demonstrate that the microsimulation runs that have been conducted have an average that is representative of the true average of the model. This does not mean to imply that the model is representative of real-world conditions. The calibration portion of this chapter (section 6.1) details the steps that should be taken to determine if the model is representative of real-world conditions. To determine the level of confidence in the reported results, an initial sampling of the model outputs is required. The initial sample will consist of the results of several simulation runs. The number of simulation runs must be large enough to reduce the impact that an atypical run will have on the sample average. To account for this, it is recommended that all model results be reported based on a minimum of 11 simulation runs. Each run must use different random number seeds starting at one and advancing sequentially. Using an odd number of runs will allow the modeler to quickly identify the run that represents the median conditions which can be used to review the model or create demonstrative videos for presentations [42]. Therefore, this research carried out 11 simulation runs with unique odd random seeds for better representation of the scenario results.

6.3.1 *Statistical Analysis for Mean Differences of queue length and average total delay in various geometric designs cases*

a hypothesis paired *t*-test based on mean differences was conducted on a sample of almost ninety observations to investigate the mean differences for two scenarios (full exclusive left turns versus roundabout). The statistical analysis was run for selected traffic performance measurements (average total delay and queue lengths). The statistical analysis reflects approximately normal distributed sample. The paired t-test was obtained to assess the mean difference between Scenario 1, full exclusive Left turn and Scenario 2, roundabout that reflects various geometric design cases. The statistical analysis was assumed with the hypothesis of no significant differences between the full exclusive left turns and the roundabout Scenario. The following tables (Tables 6 and 7) illustrate the summary of the paired *t*-test results and findings.

Table 6: Vehicle delay and Q-length paired *t*-test of Full exclusive left turns and the Roundabout.

Parameters		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference	
					Lower	Upper
Qlen (m) Y1	Y1 Y1R	52.76045	30.77310	3.28042	46.24026	59.28065
Veh delay (s) Y2	Y2 Y2R	48.93023	5.38204	.57373	47.78988	50.07057

Table 7: *t*-values for differences in Vehicle delay and Q-length for both Scenarios.

Parameters		*t*	Sig. (2-tailed)
Qlen (m) Y1	Y1 Y1R	16.083	8.49×10^{-28}
Veh delay (s) Y2	Y2 Y2R	85.285	1.236×10^{-85}

The statistical analysis study performed a paired *t*-test on the mean differences for two traffic measurement parameters of the two scenarios known as full exclusive Left turn and roundabout. The traffic measurement parameters were highlighted in Table (6) as Qlength *Y 1, Qlength Y 1R, Veh delay Y2, and Veh delay Y2R*. The statistical was conducted on a sample of almost 90 observations of queue length (m) for full exclusive Left turn and roundabout scenarios to measure the mean differences between full exclusive (*Qlen Y 1*) and roundabout *(Qlength Y 1R*). The paired t-test was also accomplished on a sample of almost 90 observations of vehicle delay (sec) for full exclusive Left turn and roundabout scenarios to assess the mean differences between full exclusive (Veh delay Y2) and roundabout (Veh delay Y2R). the statistical analysis of the paired *t*-test reflected a significant difference between the mean of the queue length parameters on full exclusive Left turn and roundabout, (*Qlen Y 1*) versus (*Qlength Y 1R*) at 95% confidence. In addition, the statistical paired t-test performed a significant difference between the mean of the vehicle delay parameters on full exclusive Left turn and roundabout, (*Veh delay Y2)* versus (*Veh delay Y2R*). In conclusion, the statistical analysis concludes that the roundabout geometric design efficiently outperformed the full and partial exclusive Left turn bays signalized intersections. The study found that the implementation of either partial or exclusive Left turn bays increased the vehicle delay (sec) and queue length (m), but it might reduce the interference and conflict between the motorist which might causes traffic conflicts between vehicles within the roundabout. The study foundlings are only relevant to the studied cases within the implemented field traffic flows and any certain variations in traffic counts might yield different results [38].

7. Conclusions and Discussion

In literature, there are few studies that have evaluated the operational efficiency of various intersection patterns in busy city intersections; however, no such studies have been conducted in Saudi Arabia. This is of importance as traffic congestion is a common problem in many cities in Saudi Arabia, and a better understanding of how various intersection designs work can help mitigate this problem. In addition, it can help identify potential areas for improvement and suggest strategies for improving intersection efficiency. One recent study conducted both analytical and simulation comparisons between networks controlled by roundabouts and those with signalized intersections featuring exclusive left-turn lanes. The findings indicate that roundabout networks generally exhibit higher free-flow speeds and trip-serving capacities. However, signalized intersections with exclusive left-turn lanes may result in lower fuel consumption per trip [52]. Similarly, research analyzed field data from the Dammam Metropolitan Area in Saudi Arabia to compare saturation flow rates between urban multilane roundabouts and signalized intersections with exclusive left-turn lanes. The study found that signalized intersections had a higher saturation flow rate on exit lanes compared to roundabouts, suggesting that signalized intersections may facilitate a higher vehicular movement rate during green phases [51]. Finally, another study compared the traffic flow performance of roundabouts and signalized intersections with exclusive left-turn lanes in Nigde, Turkey. The results indicated that implementing roundabouts increased capacity by 67.8%, reduced average delays by 72.8%, and decreased the 95th percentile queue length by 82.2% compared to signalized intersections [53].

This paper aimed to assess the operational efficiency between three different intersection patterns. The scenarios were modeled with same approaching traffic flows and the signal timing plans for both partial exclusive left turn bays and full exclusive left turn bays were considered similar. In each scenario, the performance indicators of vehicle delays and queue lengths were compared and analyzed. Results illustrated that roundabout has better operational efficiency and it lowers the overall vehicle delay by almost 85%. Similarly, in terms of queue lengths, the roundabout scenario showed a reduction of nearly 70% against the base scenario and worked better than scenario 1. The results also showed that full exclusive left turn at all approaches work more efficiently than the partial exclusive left turn intersection.

Research on these three study intersection layouts is expected to provide meaningful insights for traffic engineers and urban practitioners. Different perspectives can be used to extend it in the future. The study used fixed traffic flow for all scenarios and the future studies can explore how these different intersection layouts operate at various traffic flows [38]. Further, future studies may focus on intersection safety impact and conflict analysis, as well as operational efficiency indicators, using alternative machine learning-based approaches that rely on multi-agent simulations, and generated microsimulation models. Thus, alternative machine learning-based models will likely assist decision-makers in ensuring the efficient use of traffic control systems.

Author Contributions: Conceptualization, M.S.A.; methodology M.S.A.; software, M.S.A.; validation, M.S.A.; formal analysis, M.S.A.; investigation, M.S.A.; resources, M.S.A.; data curation, M.S.A.; writing—review and editing, M.S.A.; visualization, M.S.A.; supervision, M.S.A.; project administration, M.S.A.; and funding acquisition, M.S.A. author have read and agreed to the published version of the manuscript.

Funding: The Researcher would like to thank the Deanship of Graduate Studies and Scientific Research at Qassim University for financial support (QU-APC-2024-9/1).

Conflicts of Interest: The author declares no conflict of interest.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: The supplementary data used in the work can be obtained from the corresponding author upon reasonable requests.

Conflicts of Interest: The author declares no conflict of interest.

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Journal of Engineering and Computer Sciences
Vol. 16, No. 1, pp. 43-58 (Jan 2024)

السمات الهندسية للانعطاف يسارا: نهج المحاكاة الدقيقة لتحسين إشارات المرور

تواجه التقاطعات المُزودة بإشارات مرورية تقليدية تحديات مرورية كبيرة. أسهمت العديد من الابتكارات في أتمتة أنظمة التحكم المروري خصوصا في الإشارات المرورية في التخفيف من الازدحام المروري في هذه التقاطعات. لقد قام المؤلف بدراسة حالة تصميم هندسي في منطقة القصيم بالمملكة العربية السعودية، تتعلق بتقاطع من نوع دوار مروري حيث تم إعادة تصميم و إنشاء هذا التقاطع بطابع هندسي جديد يتضمن مسارات مخصصة جزئيًا للالتفاف لليسار. وهدفت الدراسة إلى تحليل ثلاث تصاميم هندسية مختلفة: تقاطع بإشارات مرورية للالتفاف يسارا مخصصة جزئيًا، وتقاطع من نوع دوار، وتقاطع مقترح بإشارات مرورية للالتفاف يسارا مخصصة كليًا.

تمت برمجة وتحليل الحالات المرورية الثلاث باستخدام نموذج محاكاة ميكروسكوبي(VISSIM) ، استنادًا إلى بيانات ميدانية تم جمعها من التقاطع المدروس. وأظهرت النتائج أنه، وعلى الرغم من التحسن الطفيف في تأخر المركبات وطول الطوابير (بالمتر) في حالة التصميم المقترح ذي الالتفافات اليسارية المخصصة بالكامل مقارنةً بالحالة الحالية ذات الالتفافات اليسارية المخصصة جزئيًا، إلا أن التصميم الهندسي الذي يتضمن تقاطع مروري من نوع دوار أظهر طوابير أقصر وتأخر أقل للمركبات، وذلك في مستويات معينة من حجم الحركة المرورية، مقارنةً بتصاميم التقاطعات المزودة بإشارات مرورية سواء كانت ذات التفافات يسارية جزئي أو كامل.