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Evaluation and Enhancement of Al-Warda Signalized Intersection Using Traffic Simulation Software

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Abstract:

Urban intersection is essential to the effectiveness of road networks, particularly in regions that are close to important services like government buildings, schools, and hospitals. A crucial intersection with frequent traffic jams and operational inefficiencies is the Al-Warda signalized intersection, which is situated in the center of Samawah city. The intersection still operates at an inadequate Level of Service (LOS F) even with fixed-time traffic lights, indicating the urgent need for action. This study fills this gap by using a simulation-based methodology to assess and enhance the Al-Warda intersection's performance. Two well-known traffic simulation programs are used in the study: VISSIM, which simulates traffic in great detail at the microscopic level, and Synchro 8, which does deterministic analysis based on the Highway Capacity Manual (HCM). Using video footage taken during peak hours throughout a week, the case study focuses on real-world settings. In order to create precise simulation models, geometric features, traffic volumes, and signal timings were retrieved and processed. After the model was calibrated and validated, a number of augmentation techniques were attempted, such as geometric redesign (lane widening and re-marking) and signal timing optimization. The outcomes demonstrated a notable enhancement in intersection performance. The LOS improved from F to C, and the average delay decreased from 111.1 seconds to 36.7 seconds, demonstrating a significant operational improvement. The results show how well geometric adjustments and simulation-based traffic signal optimization work together to reduce congestion at city intersections. Future studies should investigate AI-driven traffic management techniques and signal control to improve urban mobility even more.

Key words: Conflicts, Delay time, Intersection, level of service (LOS), Simulation traffic, VISSIM, Synchro 8.

1.Introduction

In both developed and developing countries, traffic congestion is a significant sociological and economic problem pertaining to the transportation sector in urban centers. Traffic bottlenecks are awful during rush hour and are frequently observed close to intersections[1]. The transportation systems power the economies of all metropolitan civilizations worldwide, hence supporting the standard of living for the inhabitants. The common urban transportation infrastructure, which includes airspace, rivers, railroads, and roadways. The majority of these are made up of the road network. It makes sense that the majority of studies and planning projects were being focused on road systems. In essence, the majority of urban regions' economic activity is heavily influenced by their road transportation infrastructure. These days, various cities are seeing significant increases in traffic and transportation demand, which has resulted in a decline in capacity and inactive operation of the traffic system[2].

Car drivers are given an indication to proceed with their journey through traffic signals, which are electrically controlled traffic control systems that grant right-of-way to all approaching and merging traffic. Municipal and state agencies use traffic signals, a well-liked form of traffic control, to address operational and safety issues with roads. Through identifying competing motions in time and allocating delays, they allow for the shared use of road space and may be used to improve the accessibility and security of such motions [3]. An intersection is a location where two or more roads meet. Its main objective is to allow drivers to change their route and to enable planned traffic movements in that area. A simple intersection is one where 2 roads cross at right angle, and a complicated intersection is one that serves at least 3 crossing roads in one location. Intersections could be categorized based on their level of complexity [4].

The comfort of passengers and drivers on any highway or street within a road network is affected by operational state of the intersections. Accordingly, intersections are governed by stop signs or highway traffic control signals [5]. Intersections could be categorized based on the quantity of approaches that enter the intersection area and the kind of control that is utilized [6]. Because of lower volumes and traffic densities, Saturation Flow Rate (SFR) value at intersections in the CBDs (i.e., central business districts) and metropolitan areas is typically lower than in outlying regions. Give way control, roundabouts, traffic signals and stop control are a few different forms of at-grade intersection traffic management [3, 6].

At signalized junctions, one of the best methods to cut down on delays is to improve traffic flow. Therefore, generating appropriate signal timing and improving geometrics through the use of optimization tools could significantly reduce delay and increase LOS at such intersections. In order to optimize signals, it is necessary to incorporate field observations of geometric features and signal performance in addition to current traffic flow data. According to the study, signal timing optimization is one of the best strategies used to reduce traffic bottlenecks and delays and improve the operation of signalized crossings [7, 8].

Level of service (LOS) is a tool that transportation planners can use to confirm the quality of service provided by a certain infrastructure or transportation facility. When drivers seem to be undisturbed by other automobiles in the moving traffic stream, their LOS is at its highest (A), and it is at its lowest (F). The average stopping delay of time per vehicle can be used to calculate LOS for signalized junctions[1, 9]. At intersections with signals, traffic congestion is at its severe. Even when the volume of incoming traffic is far less than capacity, traffic signals still result in bottlenecks and delays to movement [10]. When characterizing the operational conditions of signalized crossings, the LOS impression obtained from a measurement of the control delay is a crucial component [11]. Delay is the quantity of time lost at signalized crossings due to traffic, geometrical aspects, and control conditions at the intersections. Inadequate road geometry factors coupled with poor signal timing at signalized crossings can result in delays and a reduction in throughput [12, 13]. If these issues are not resolved, drivers' comfort at the LOS may suffer. Improving the performance of signalized crossings has a major

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impact on the overall efficiency of highways since the operational conditions of these intersections affect the comfort of both drivers and passengers.

For the analysis and optimization of signalized, microsimulation techniques like as VISSIM have become indispensable. VISSIM makes it possible to model traffic interactions in great detail, which makes it possible to evaluate different design and control situations. For example, research that used VISSIM to model roundabout traffic operations demonstrated how well it works for assessing various traffic circumstances and control tactics [14, 15] .The significance of left-turn lanes in increasing intersections capacity and safety has been emphasized in earlier research. While Hellinga & Abdy (2008)[16] highlighted the importance of signal timing in maximizing intersection efficiency, Liu et al. (2007) [17] showed that designated left-turn lanes minimize delays and conflicts. Few studies, nevertheless, have used simulation models to thoroughly assess how different traffic loads and signal phasing affect left-turn lane performance. This study closes this gap by using a reliable simulation technique to examine intersection performance data, offer insights into the state of traffic, and suggest possible fixes to enhance the region's overall traffic performance.

2. Al-warda Signalized Intersection as case study

This crossroads in Samawah City is one of the most important ones in the city center. It is a four-leg signalized intersection with four signal phases that is controlled by a fixed time signal. At this crossing, a lot of lively action occurs. Connecting Al-Furat and Dijla Street from the east with Al-Bee'a Street from the west and Al-Gharbi Street from the south with Mohammed Ali Street from the north, it is a four-leg signalized intersection. The presence of many significant locations close to the intersection, including as the Al-Samawah General Hospital, the Al-Muthanna Treasury Directorate, and a few primary schools, led to traffic congestion in the morning, midday, and evening hours. The case study seen in Figures (1.a, 1.b). The following is the Geometric of Features for this intersection is displayed in Table 1.

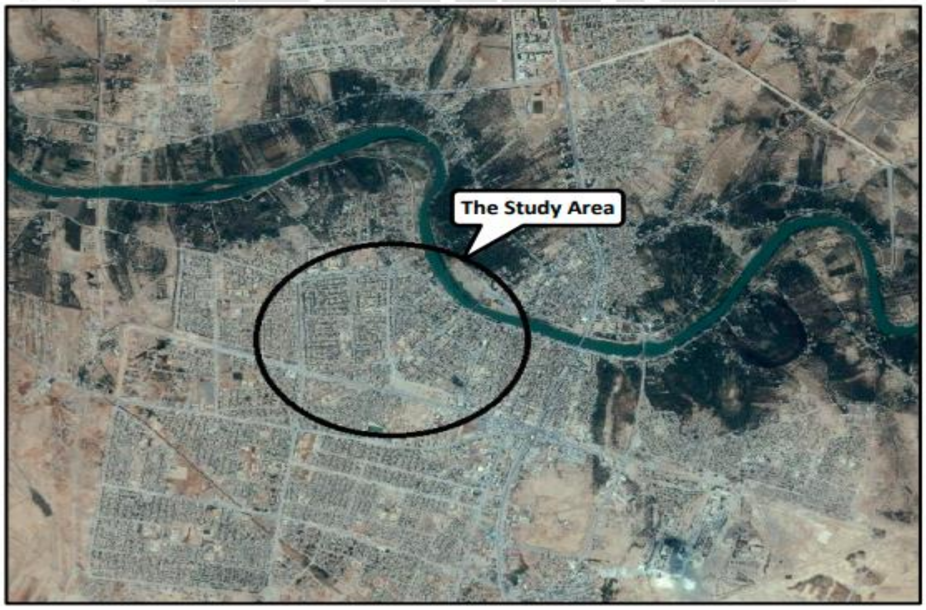

Fig. 1.a. The study area in Samawah City

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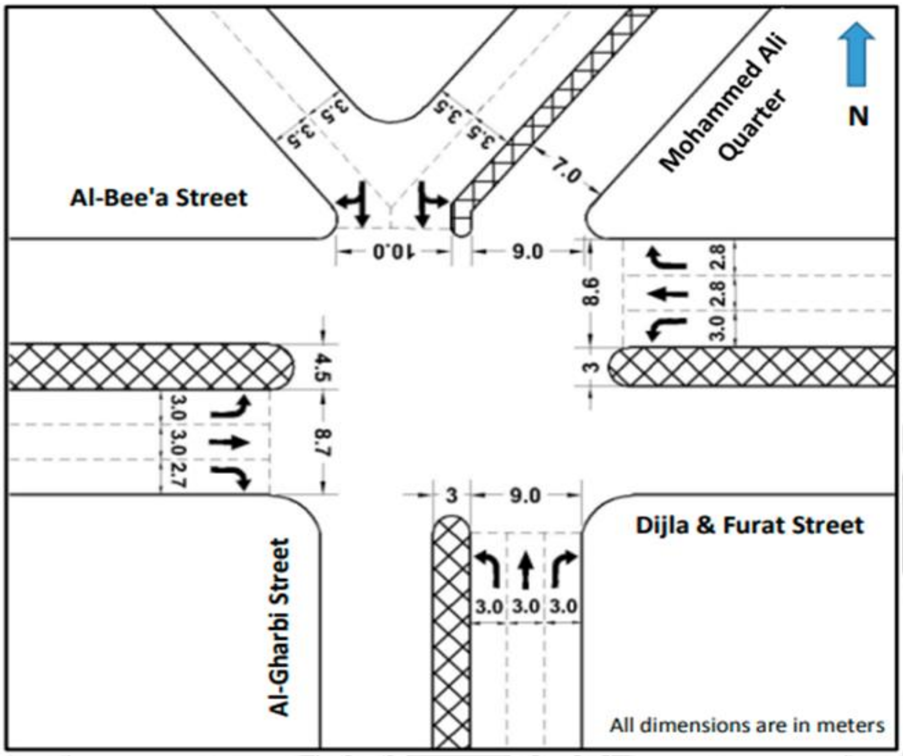

Fig. 1.b. Layout diagram of Al-Warda intersection

Table 1. Geometric of Features of the Al-Warda intersection

Approach	Entry Width (*We*)	Exit Width	No. of Entry lanes	Entry Radius (*Re*)	Splitter Island Width
	(m)	(m)	No.	(m)	(m)
North	10.0	9.0	2	3.5	1.0
South	9.0	9.0	3	4.5	3.0
East	8.6	8.6	3	3.0	3.0
West	8.7	8.7	3	4.5	4.5

3. Methodology of data collection

It has been crucial to follow the planned processes to collect necessary data in order to meet the goals of the study. These processes can be divided into four categories, which are outlined below:

1. Defining specified the input data for selected software.

2. Define the peak hour periods.

3.Describing the limitations that are related to the study area.

The primary goal of gathering geometric data for signalized intersections is to assess as well as improve traffic by widening a lane, building an underpass or overpass, or adding a new lane. A portion of the geometric data was gathered through the use of GIS methods, map measurements, and the availability of 60-cm-accurate satellite images of Samawah City. The level instrument is used to calculate the slopes of each intersection. Certain geometric aspects, like the presence of exclusive RT or LT lanes, the number of lanes per approach, and parking, are observed. Field measurements, like the lane width and median width, are gathered with the use of a measuring tape. A traffic simulation model was used as part of the methodological process to assess the signalized intersection by tracking stopped vehicle and delays in real time. The framework for the methodology of research is shown in Figure 2.

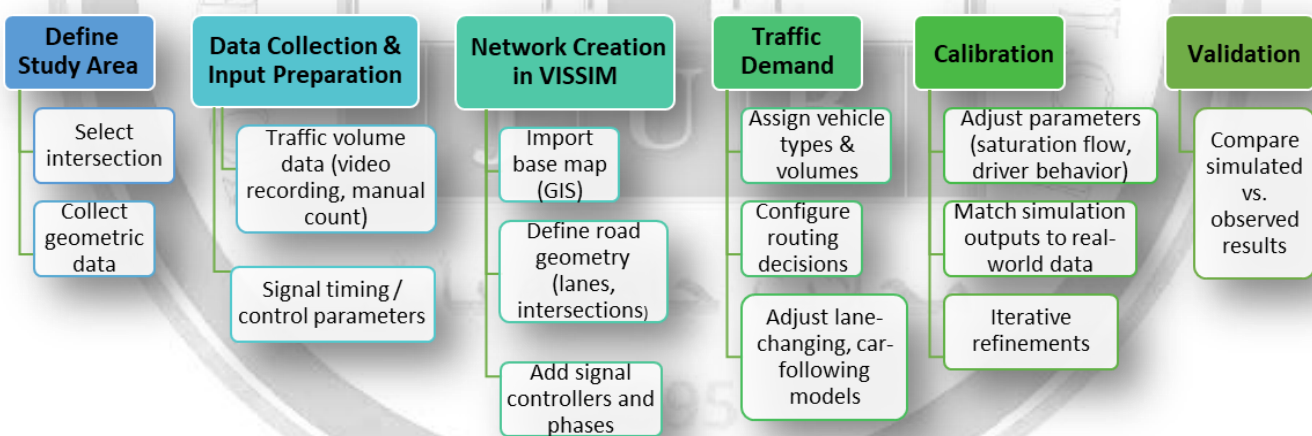

Fig. 2. Framework for Model Development and Assessment in Research Methodology

Traffic volume data were gathered over one-week period using a video recording method during three distinct peak periods: 7:00- 9:00A.M. in the morning, 1:00-3:00P.M. in the afternoon, and 5:00-7:00P.M. in the evening. These data were gathered following extensive personal observations and the completion of pilot surveys within the study area. In addition, a number of in-person interviews are conducted with interested parties, including a number of road users and traffic police officers stationed in the research region, to ascertain the busiest times of day for gathering traffic data. The video was recorded under typical circumstances, with dry, bright weather and decent visibility. Based on all those factors, it has been determined that the Al-Warda intersection experiences morning peak hour traffic between 7:30 and 8:30 A.M., as depicted in Figure 3. To guarantee consistency, the identical geometric circumstances and traffic data during peak hours were entered into the Synchro 8 & VISSIM models. Both simulations employed a similar signal cycle length of (95 s) to allow for a fair comparison.

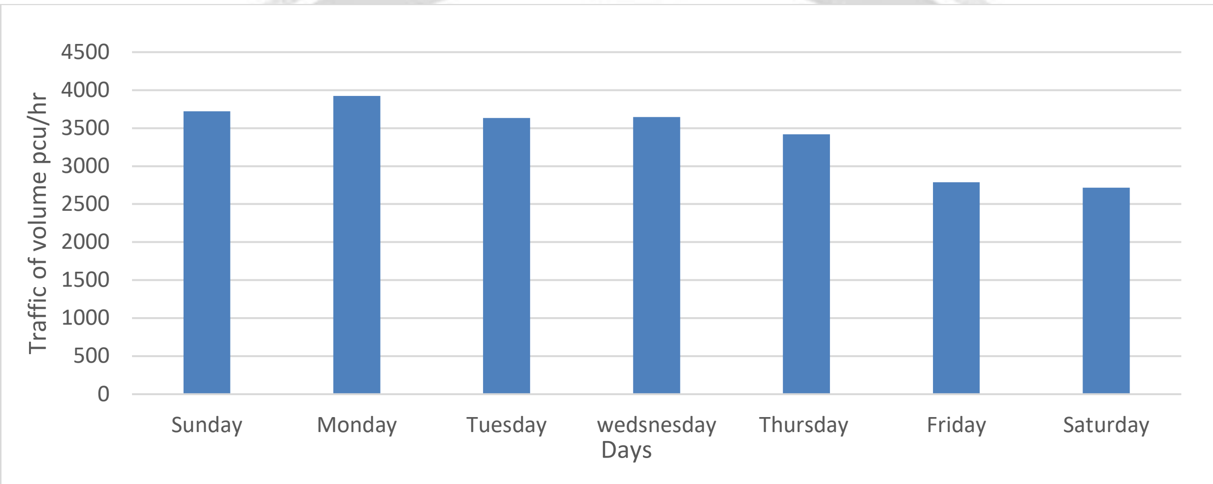

Fig. 3. Traffic of Volume at Al-Warda Intersection

Traffic volumes that are abstracted from video recording for every approach at the intersection are all included in this data. According to HCM 2000, traffic volume is converted into PCU (i.e., passenger car units) through the multiplication of each type of car by its factor. The video film is used for measuring cycle duration, green time, phase length, and all red time for signalized intersections.

4. The Software Application SYNCHRO 8

SYNCHRO 8 was utilized to simulate traffic flow within the selected intersection. It is a complete programming tool for designing, simulating, and refining traffic systems. Table 2 shows that much of the junction has high overall delay values because of oversaturation and an unacceptable (LOS F) level of service. This section outlines the method of the traffic flow improvement that were implemented at the chosen intersection using the SYNCHRO 8 calibrated software. One of the most economical ways to lower vehicle running costs and enhance traffic flow efficiency on urban roadways is traffic signal timing optimization. SYNCHRO 8 has several types of optimizations. For reducing the delay time and stop, it optimizes the lengths of the cycle, split times, and phase sequences.

SYNCHRO 8 optimizes splits for the length of the cycle that starts with shortest cycle length. SYNCHRO 8 will need to attempt a longer length of the cycle until percentile critical traffic is eliminated if the split for each phase is unable to remove the traffic. The splits for each

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phase will be automatically determined by the optimal splits order. Each lane group determines how time is divided, and each traffic volume is split by its modified saturation flow rate. When possible, splits optimization will result in the estimation of the least number of splits sittings for each phase. HCM recommends a cycle length range of 60-120 seconds. It will be advised to choose a cycle length 95 seconds in order to accommodate additional 10% of capacity. Cycle times more than 120 seconds may have undesirable operational effects, such as blocking, lengthy lines, and inefficient turning lane usage. Low cycle length may be preferable in order to shorten the line, increase capacity, and provide more efficient traffic flow. As a default setting provided by SYNCHRO, the cycle times employed in the process of optimization ranged from 50 to 200 sec.

The impact on the measure of effectiveness (MEO) for Al-Warda signalized intersections has been minimized by using optimization functions, like split optimize and cycle length optimize. In the case the delay decreased from 111.1 to 96.6 seconds, this change did not reach the needed level, indicating that the intersection must try geometric improvement.

Table 2. Traffic Volume Data Sample and average delay for Intersection Al-Warda

Name of the Intersection	Approaches	Traffic volume	LOS	Average delays
Al-Warda	North	1215	F	230
	South	1172	F	87.3
	East	942	D	42.2
	West	595	C	24.4
Summary: average delay = 111.1sec LOS = F V/C = 1.53				

5. VISSIM Software Application

To replicate the current traffic flow at the chosen intersection, VISSIM was used. VISSIM serves as one of the most common tools for the microscopic simulation of the diverse traffic dynamics. The model permits in-depth study of the motorists, their vehicles, and the road layout. As seen in Figure 4, the desired speed of the reduced region inside the intersection was used to modify the geometric delay, which was calibrated according to the time to pass the intersection. The standard speed distribution was justified by selecting the rectangle distributions between 12 and 38 km/h, since the intended speed distributions was based on the field data that was surveyed utilizing a global positioning system (GPS). A number of researches have proven that VISSIM works effectively with intersection, which will be sufficient for the purpose of this study. Figure 5 shows that the VISSIM model used a perfect cycle duration of 95 seconds, which satisfied the lowest average values for the chosen intersection. The design phases, phase duration, yellow, RT- right turn on red and all red periods, cycle length, maximum green, and traffic signal controllers and signal heads are all included in this.

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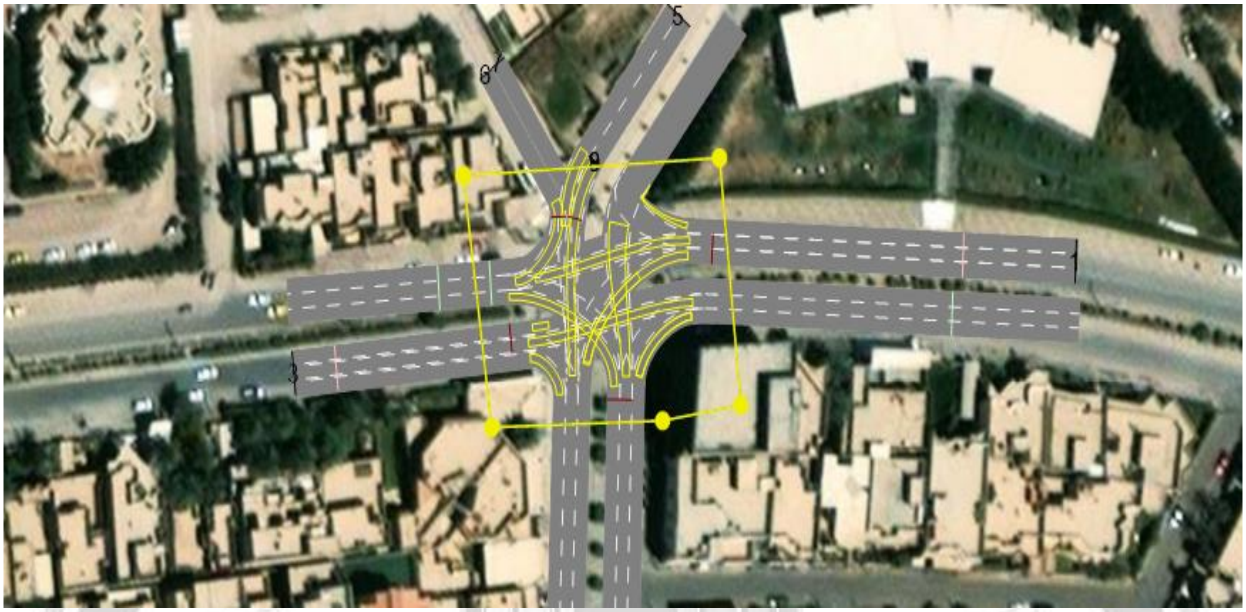

Fig. 4. A reduced speed zone for intersections with signals

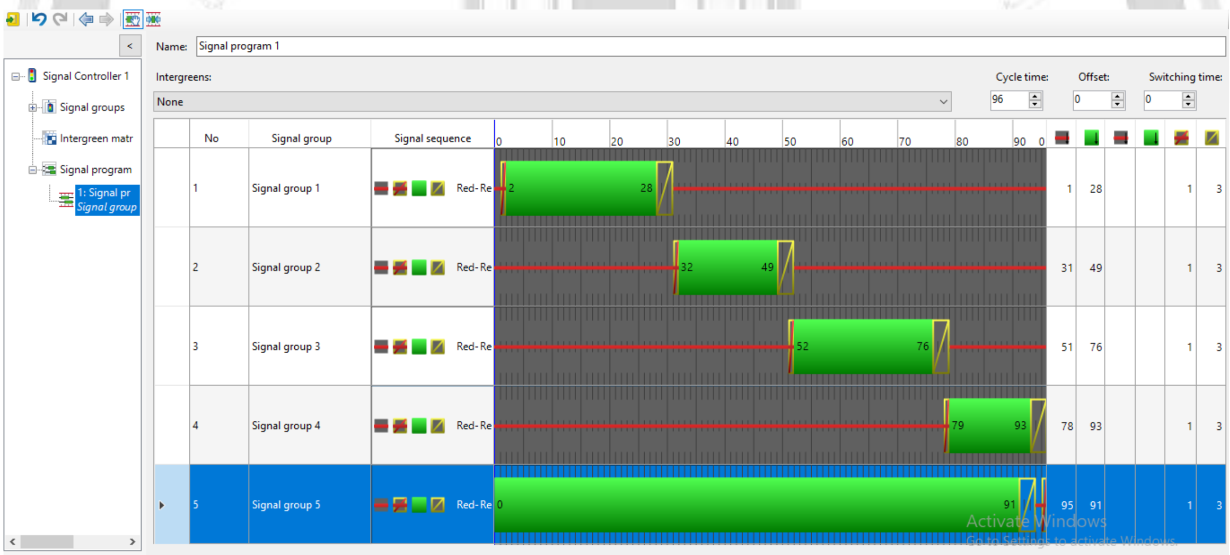

Fig. 5. Signal Phase Plan for Simulation using VISSIM

This study combined Synchro 8 and VISSIM in a dual-simulation technique to get a thorough evaluation of the operational performance of the Al-Warda intersection. Each piece of software has unique features that enhance the others. Synchro 8 is appropriate for rapid calculation of Level of Service (LOS), average delays, as well as volume-to-capacity ratios because it is based on deterministic approaches derived from the Highway Capacity Manual (HCM). Its analysis is constrained by oversimplified assumptions, though.

VISSIM, on the other hand, makes microscopic simulation possible while taking into consideration complicated geometry conditions, driver behavior, and real-time vehicle interactions. As a result, traffic dynamics under various conditions can be modeled more realistically. When both instruments are used together, the evaluation of current circumstances and suggested improvements is more accurate. VISSIM verified and optimized possible enhancements in a dynamic as well as calibrated environment, whereas Synchro functioned as a baseline tool to identify congestion hotspots. Reliable decision-making backed by realistic simulation results and empirical data was made possible by this hybrid methodology.

6. Improved Technology VISSIM Interconnection Simulation

In this section, will discuss the approaches that help enhance vehicular movement on the selected intersection using simulation software VISSIM. The improvement methods are divided into two parts depending on the software used and the approaches utilized.

6.1 Cycle Length Optimization Technique

Traffic signal optimization alone is one of the most effective approaches towards lowering the cost of operating vehicles while increases traffic flow on urban streets. VISSIM gives users the most sophisticated functionality for optimizing cycle lengths, split times and phase sequences, in addition to offering microscopic simulation of traffic flow. To improve traffic signal control in VISSIM, the movement of the street traffic is simulated on a micro level considering movements of particular vehicles, the actions of aggressive drivers, and social interactions of drivers. The algorithm is set up in the following steps:

1. Constructing The Intersection: The shape of the intersection, the number of lanes, and the traffic volume are constructed in VISSIM. Timing control parameters (cycle length with reference to phases, phase splits and offsets) are defined in the model.
2. Cycle Length Adjustment. VISSIM uses a baseline cycle length value of 120 seconds and methods to eliminate delay and stopping as a leading approach. The software assesses the effectiveness of other cycle lengths (50 to 200 seconds) mitigating delays as prescribed, as recommended by HCM) on key performance metrics such as delay, queue length, and level of service (LOS).
3. Split Optimization: Changes in traffic volumes and saturation flow rates will automatically adjust the phase splits on VISSIM. The system balances flow-sensitive movements with critical green light phases whilst giving the necessary diminishing green phases to other rivaling movements.
4. Performance Evaluation: Key outputs such as average delay, queue length, number of stops made, and LOS are provided by VISSIM. The software supports multiple scenarios like varied cycle lengths, phase orders, as well as changes in the geometry of the intersection.

Key Considerations for Cycle Length: HCM Recommendations: Within limits of 60 to 120 seconds, an intersection's cycle length is most effective. Restriction cycles over 120 seconds may result in operational problems, including blocking, excessive queues, and poor usage of turning lanes. Capacity and Delay Trade-Offs: Increased cycle length can lead to additional holding capacity, but this increase can also prolong minor burst delays. Reduced cycle length may relieve delays, but could also lead to congestion.

6.2 Geometric Improvement Analysis

If there are parking where the level of service achieved is not satisfactory through signal optimization alone, it is possible to appraise the geometric improvements through VISSIM. The program allows for simulation of various geometric modifications such as: Adding or removing lanes, changing lane width and turning radius, adding dedicated turning lanes or phases and preventing parking on both sides of the road. VISSIM allows for combining the geometric modifications with signal timing optimization to achieve a more integrated approach to intersection improvement.

The following strategies will be needed to enhance the oversaturated approach geometries at Al-Warda intersections:

- Pavement Re-marking.
- Pavement widening.
- Overpass Construction
- Intersection type alteration.

Pavement remarking is the initial step in the process of geometric improvement. This phase took into account marking the oncoming lanes to facilitate the rearranging of vehicles in line at the stop. Moreover, the application of exclusive lanes to divide traffic-heavy movements is frequently used. Following the application of each enhancement type, signalized intersections undergo optimization. The second trail concerned pavement widening. Based on the measurement, it is evident that, in many methods to such intersections, the number of lanes could be increased by reducing lane width as long as the lane width remains greater than the smallest value of 2.4m, as recommended by HCM a method that is in fact observed to be utilized in the field. The increase of the number of lanes will enhance certain intersections' traffic performance MOE (i.e., measure of effectiveness) by raising saturation capacity of the impacted methods. Pavement re-marking is applied at the intersection.

Al-Warda intersection's delay value was improved and decreased to 36.7 seconds with an acceptable level of services (LOS C) by implementing the second approach, which is pavement widening by reducing the line width and adding a fourth lane. The third experiment was a suggestion for an overpass; however, there was not enough room surrounding this intersection to implement the strategy, nor could it be changed to a roundabout within the intersection area.

7. Calibration and Validation of Traffic Simulation in VISSIM: A Case Study of Al-Warda Intersection

VISSIM and other microsimulation models are frequently used to analyze and improve traffic management at crossings [18]. However, a thorough calibration and validation procedure must be carried out to guarantee that the model faithfully captures real-world circumstances. While validation verifies the model's predicted accuracy, calibration entails modifying the model's parameters to match the simulated outcomes with observed traffic data [19]. Using empirical data gathered by video recording, this work offers the validation and calibration of a VISSIM simulation for Samawah City's Al-Warda signalized intersection.

7.1. Calibration of the VISSIM Model

In order to simulate actual flow of traffic at the Al-Warda intersection, important VISSIM parameters had to be changed during the calibration process. The actions listed below were put into action [20].

Driver Behavior Adjustment: To align with observed congestion patterns, parameters like reaction times, lane-changing aggression, and car-following sensitivity were adjusted. Traffic Demand Scaling: To guarantee consistency with actual peak hour circumstances and take traffic swings into account, the input quantities were adjusted. Signals Timing Optimization: The model was built using the fixed-time signal settings that were first recorded. Phase splits and offsets were adjusted to match actual time of the queue length as well as delays in order to fine-tune. By contrasting real data with predicted travel times, delays and queue length, calibration performance was evaluated. The measure of effectiveness (MOE) criteria included the average control delay, vehicle stops, and saturation flow rates [21-23].

7.2. Validation of the VISSIM Model

After calibration, the model was validated using an independent dataset collected on different days. The validation process involved: Statistical Comparison: The Root Mean Square Error (RMSE) and Mean Absolute Percentage Error (MAPE) were calculated between observed and simulated traffic parameters to ensure that discrepancies remained within acceptable thresholds (typically ≤ 10%). Graphical Analysis: Scatter plots and regression models were used to compare simulated and observed vehicle counts and delays across different approaches of the intersection. LOS (Level of Service) Verification: The VISSIM-generated LOS values were compared against empirical HCM-based calculations to confirm model accuracy [24-26].

8. Discussion

Based on Table (3) findings, conclude the following conclusions: Total delay simulation results were obtained using a post-calibration VISSIM- model and contrasted with field data observations. According to Table 2, which provides a full comparison, the error percentage for each intersection model approach ranged from 3.91% to 8.26%. This is below 10% and suggests that the simulation delay findings and the observed field data closely converge. The VISSIM calibration model was therefore considered complete. In order to complete the validation of the simulation model in the following phase of this methodology, the results of the halted delay from the calibration model's simulation showed that the percent error acquired from the validation model for all approaches was less than 10%, indicating that the simulation results are in good agreement with reality. As a result, the VISSIM simulation model was successfully calibrated and validation as shown in Figures 6,7.

Comparative analysis shows consistent patterns across both models, even though Synchro 8 & VISSIM simulation results are presented separately in Tables 2 and 3, respectively. The VISSIM model was calibrated & validated against actual field data to offer a more realistic simulation, while the vehicle's delay and LOS values from Synchro were used as an initial baseline. Both techniques validated the critical congestion levels at the Al-Warda intersection as well as the need for operational adjustments, even though they were modeled independently.

The Al-Warda intersection's existing geometry includes entrance widths between 8.6 and 10.0 meters, primarily three-lane approaches, fixed signal phases, and no designated turning lanes. With a baseline LOS of (F) and an average delay of 111.1 seconds, this configuration causes extreme congestion during peak hours, especially in the north and south approaches where delays surpass 200 seconds. VISSIM was used to model a number of geometric enhancements in order to address these shortcomings. These comprised: Remarking the pavement will enhance vehicle alignments at stop signs and reorganize lane usage. Increasing the number of lanes from two to three while keeping the lane width over the HCM min. of 2.4 meters, particularly on the northern approach. Due to space constraints, a hypothetical overpass was taken into consideration but ultimately rejected.

These actions improved the overall LOS to C and decreased the average delay at the intersection to 36.7 seconds. The improvements were deemed viable for practical implementation within Samawah's current urban fabric due to their cost-effectiveness and spatial viability.

Table 3. Measurement of Error % in the Validation and Calibration Model

Approach	Average of Vehicle Delay (sec/veh)		Error (%)	Stopped of Delay (sec/veh)		Error (%)
	The Field of Data Observed	Results after Calibration		The Field of Data Observed	Simulated Results	
Northbound	250	239	4.4	210	226	**7.6**
Southbound	95	91	4.2	76	70	**7.89**
Eastbound	59	54	8.75	35	37	**5.71**
Westbound	**32**	**29.2**	**7.38**	**15**	**16**	**6.67**

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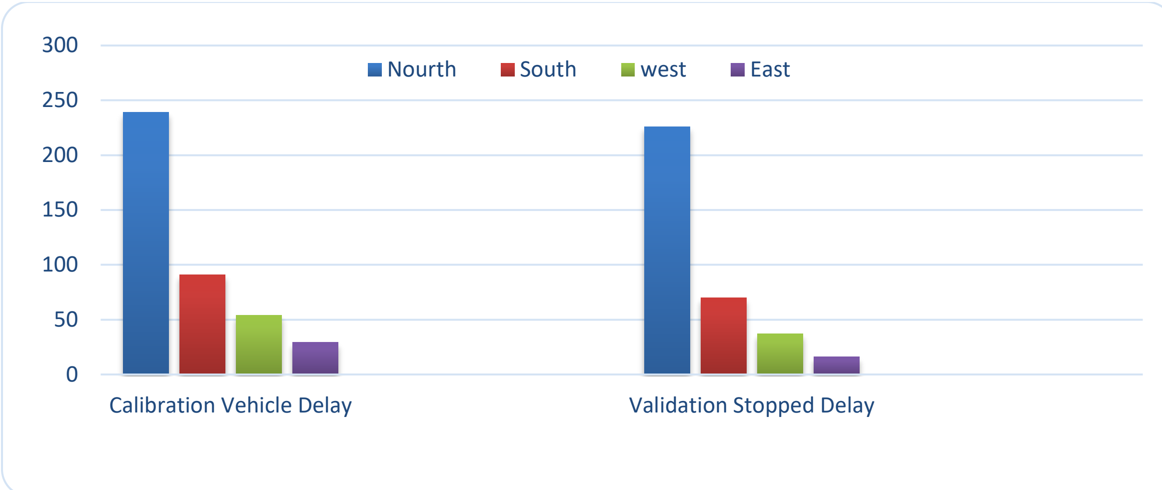

Fig. 6. Validation and calibration for Signalized Intersection for Every Approach

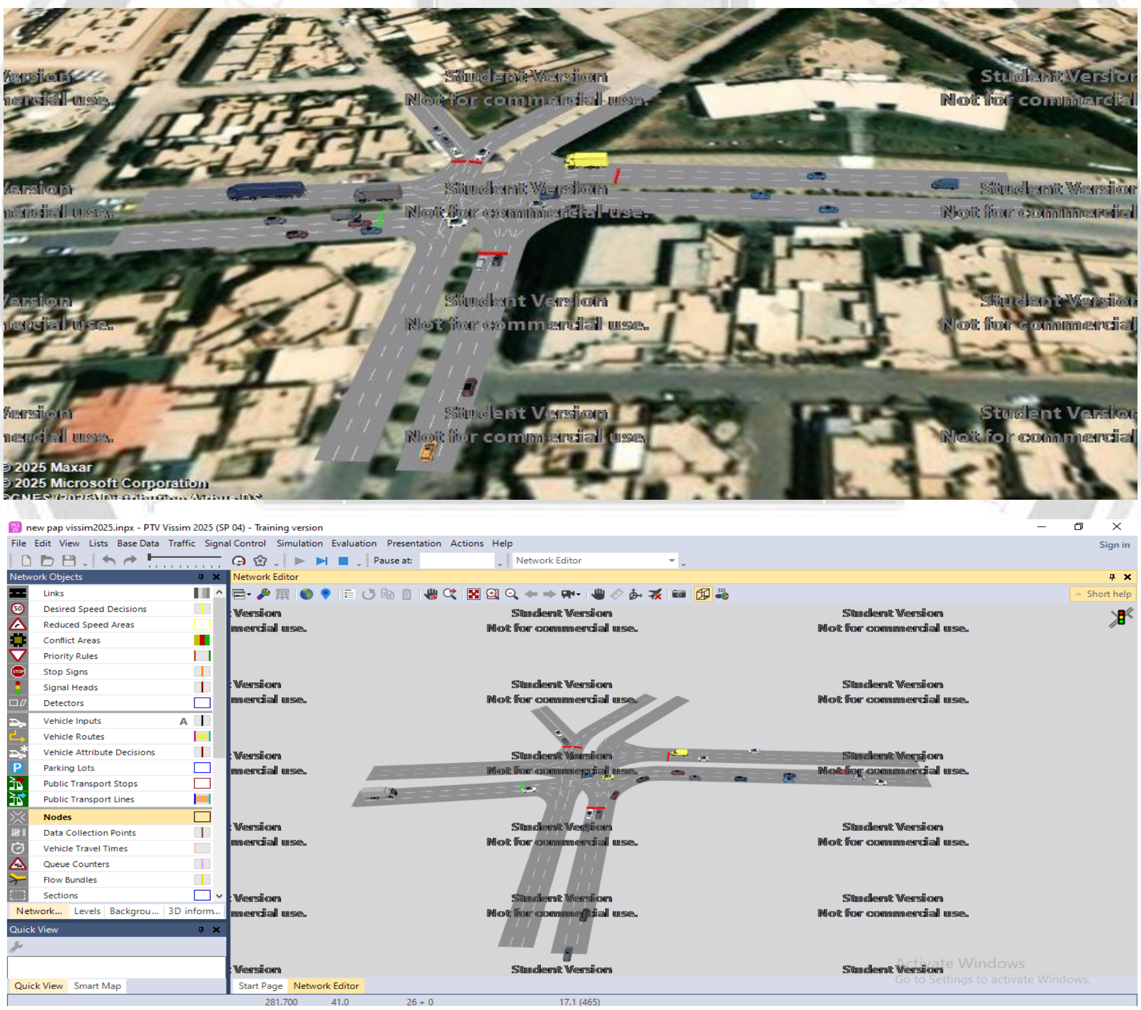

Fig. 7. Visualization of the Exclusive Right-Turn Intersection VISSIM Simulation Model

9. Conclusion and Recommendation

The following are the main considerations based on the AL-Warda Intersection's operational research conclusions, available free land, and traffic survey results:

1. According to the Highway Capacity Manual, the study area of Al-Warda intersection has extreme congestion on 4 approaches, resulting in a LOS that is at minimum requirements (which is level F).
2. Because of the huge volume of traffic, employing SYNCHRO 8 software to optimize signalization timing and include splits of all phases and phases sequences isn't an efficient way to increase the performance traffic of operation.
3. By using a combination of design and operational measures, the extreme traffic at the intersection can be reduced. These include removing on-street parking, which decreases effective lane width, enlarging the current road to handle increased traffic volumes, and clearing up encroachments that impede traffic flow, whether they be legal or not. Furthermore, implementing focused traffic control strategies, such enhanced signage, dedicated turning lanes, as well as optimal signal phases, can greatly increase traffic capacity and decrease delays during peak hours. The intersection's delay value has been enhanced to 36.7 seconds and LOS C thanks to the pavement widening approach of the geometric improvements
4. The successful calibration and validation of the VISSIM model demonstrate its applicability in evaluating and optimizing urban intersections. The refined model provides a reliable framework for testing further improvements, including adaptive signal control strategies and geometric modifications. Future research may explore real-time traffic signal adaptation using AI-based predictive modeling.
5. Because bus rapid transit (BRT) gives signals priority, it may be able to enhance the quality of life for riders at extremely crowded signalized crossings. Each of the previously listed tactics has the potential to lower environmental pollution and fuel usage.

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تقييم وتحسين تقاطع الوردة المزود بإشارات ضوئية باستخدام برنامج محاكاة المرور

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الخلاصة

تُعدّ التقاطعات الحضرية أساسيةً لفعالية شبكات الطرق، لا سيما في المناطق القريبة من الخدمات المهمة كالمباني الحكومية والمدارس والمستشفيات. يُعدّ تقاطع الوردة المُزوّد بإشارات ضوئية، الواقع في قلب مدينة السماوة، تقاطعًا حيويًا يشهد ازدحامًا مروريًا متكررًا وضعفًا في الكفاءة التشغيلية. لا يزال التقاطع يعمل بمستوى خدمة غير كافٍ (LOS F) حتى مع وجود إشارات مرور ثابتة التوقيت، مما يُشير إلى الحاجة المُلحة إلى اتخاذ إجراءات. تُعالج هذه الدراسة هذه الفجوة باستخدام منهجية قائمة على المحاكاة لتقييم أداء تقاطع الوردة وتحسينه. استُخدم في الدراسة برنامجان معروفان لمحاكاة حركة المرور: VISSIM، الذي يُحاكي حركة المرور بدقة متناهية على المستوى المجهري، وSynchro 8، الذي يُجري تحليلًا حتميًا استنادًا إلى دليل سعة الطرق السريعة (HCM). باستخدام لقطات فيديو مُلتقطة خلال ساعات الذروة على مدار الأسبوع، تُركز دراسة الحالة على بيئات واقعية. ولإنشاء نماذج محاكاة دقيقة، تم استرجاع ومعالجة السمات الهندسية، وأحجام حركة المرور، وتوقيتات الإشارات. بعد معايرة النموذج والتحقق من صحته، جُرِّبت عدة تقنيات لتحسين الأداء، مثل إعادة التصميم الهندسي (توسيع المسارات وإعادة وضع العلامات) وتحسين توقيت الإشارات. أظهرت النتائج تحسنًا ملحوظًا في أداء التقاطعات. تحسّن مستوى الخدمة (LOS) من F إلى C، وانخفض متوسط التأخير من 111.1 ثانية إلى 36.7 ثانية، مما يُظهر تحسنًا تشغيليًا ملحوظًا. تُظهر النتائج مدى فعالية التعديلات الهندسية وتحسين إشارات المرور القائم على المحاكاة في تقليل الازدحام عند تقاطعات المدن. ينبغي أن تدرس الدراسات المستقبلية تقنيات إدارة المرور والتحكم في الإشارات القائمة على الذكاء الاصطناعي لتحسين التنقل الحضري بشكل أكبر.

الكلمات الدالة: التعارضات، زمن التأخير، التقاطع، مستوى الخدمة (LOS)، محاكاة حركة المرور.