




# Assessing and Optimizing Traffic Congestion in Muaskar Al-Rashid Highway Interchange in Baghdad

Tamarah Sameer Victor\*, Ahmed Subhi Abduljabbar, and Ammar Abbas Mohammed

Civil Engineering Department, University of Technology, Baghdad, Iraq

\*Email: [bce.21.53@grad.uotechnology.edu.iq](mailto:bce.21.53@grad.uotechnology.edu.iq)

Article Info	Abstract
<p><b>Received</b> 29/03/2024</p> <p><b>Revised</b> 04/05/2025</p> <p><b>Accepted</b> 01/06/2025</p>	<p>The Muaskar Al-Rashid interchange is one of Baghdad's most important interchanges, where traffic congestion is high during the hours of 7:00–9:00 am and 1:00–3:00 pm. The study aims to ensure maximum traffic safety and capacity on modern highways, improve the level of service (LOS), and assess the impact of pedestrians on traffic and their safety during crossing. A set of procedures was used to evaluate the interchange using the VISSIM analysis program and the HCS program to improve the cycle time of traffic signals. Geometric measurements of the intersection were collected using the Geographic Information Systems (GIS) program. The results indicated LOS F, and the total number of pedestrians was 1,413. Several proposals have improved it, including a geometric redesign of the interchange, the implementation of Transportation Demand Management (TDM) strategies, and a change in vehicle movement patterns. The solutions were applied to current traffic volumes and the forecasted traffic volumes in five years. Simulation results show that the reversible route design proposal is more economical and the most appropriate solution. The average travel time is reduced by 81%, and the average stop delay is reduced by 80%.</p>

**Keywords:** Average travel time, Al-Rashid Highway interchange, Muaskar, Pedestrians, Queue length, Traffic congestion, VISSIM program.

## 1. Introduction

An increase in vehicle use leads to high levels of traffic congestion on major roadways, a problem that all major cities face. Due to the demand volume exceeding the capacity of the roadways, oversaturation situations developed, creating unstable conditions that impacted the capacity of the major arterials. The most significant number of vehicles per hour or day is the definition of a road's capacity. Studying the organization of interchange traffic is essential for resolving the current issues associated with interchange traffic congestion. The current work delves into the operation characteristics of diamond interchange traffic and its organization, pinpointing challenges that still require resolution. Several elements influence capacity, including traffic patterns, environmental variables, and geometric design aspects (lane width, the mean, points of entry, pavement and shoulder conditions, etc.) [1]. Roads and highways are an essential part of Iraq's transportation infrastructure and play a significant role in the growth of the community and its economy. These infrastructures must provide daily traffic operations that are secure, economical, and of high quality. Therefore, a rise in demand will immediately

correlate with increased car usage and available highway access. Iraqi highways need to be reevaluated, and plans should be made to enhance the level of service. This LOS suffered due to the increase in cars, necessitating research into the issue's root causes and identifying workable solutions, whether for now or in the future [2]. The VISSIM simulation tool is used in this paper to develop and assess the functionality of a signalized intersection [3]. The local transportation engineers observed that the Tight Diamond Interchange (TDI) design could not meet traffic needs due to annual traffic growth. In terms of operational efficiency, the majority of research conducted at the time consistently indicated that the Single Point Urban Interchange (SPUI) outperformed the Tight Diamond Interchange (TDI). As a result, the SPUI design finally replaced the TDI design.

The interchange was changed to SPUI with a frontage road (SPUI-F) [4]. This study excluded the diamond-shaped roundabout from its scope. Most agencies do not view a single point diamond interchange (SPDI) as a competitive alternative. They came up with the concept for the super diverging diamond interchange (DDI) design while researching different

interchanges. The synchronized interchange, drawing inspiration from the Super Street intersection design, demonstrated remarkable performance in high-traffic situations [5]. It is necessary to upgrade infrastructure, such as waiting stations, and improve service, dependability, safety, and travel information for public transportation to enhance its appeal. The cost is one crucial factor that affects the demand for public transport [6]. Most transportation organizations understand how important it is to create pedestrian-friendly, quick, and safe routes. Because pedestrians interact with other forms of transportation, providing an acceptable state for them requires special care at junctions and service interchanges. There are three stages to the analysis: A broad comparison of pedestrian performance designs concerning safety, trip time, and service quality; an examination of how vehicle performance affects pedestrians; and Modeling of how pedestrians affect vehicle traffic operations [7].

To investigate the pedestrian performance of interchanges across a range of traffic volumes, turning traffic ratios, traffic distribution, and heavy vehicle percentage scenarios, the authors conducted extensive simulation tests using VISSIM. That said, pedestrian travel times were shorter in all current designs than in new ones, except for the diverging diamond interchange (DDI). One of the most well-liked alternative interchanges, the DDI, performed the worst across the board, according to pedestrian research. Pedestrians may significantly increase vehicle travel time through a diamond, even if a typical diamond interchange performs fairly well regarding pedestrian travel time and safety [8]-[10].

The study evaluates the interchange's performance for the current traffic volume in 2023 and the future after 2027. The VISSIM Micro-simulation Program simulates factors such as interchange shape and the number of vehicles on approaches. The study encompassed the majority of interchange issues, given the presence of residential and industrial buildings in the area that significantly impact the region. This intersection requires traffic signals, as observed in the field before developing the simulation model. Specifying the minimum, maximum, yellow, and green times is necessary. The proposed scenarios for relieving congestion were acceptable, according to the evaluation results produced by the VISSIM program.

## 2. Background

An expanding body of literature examines the operational characteristics, use, and safety challenges of interchanges. Previous studies that are connected to the development of interchanges in Iraq are displayed below:

The author's study attempts to compute travel time reliability for a portion of the Abi Talep urban arterial street in Baghdad, the capital of Iraq. The study starts at the Al-Shaab Bridge intersection and ends at the Al-Nidaa intersection. In terms of the 95% percentile travel time, this ratio is considered realistic for a busy road in Baghdad [11].

There are four interchange designs: the super DDI-1, the super DDI-2, the DDI, and the current CDI (conventional diamond interchange). The authors attempted to broaden the field's understanding of the innovative super diverging diamond

interchange (super DDI) design by assessing its operational effectiveness at actual sites [5].

Focusing on transportation demand management (TDM) to reduce vehicle pollution and congestion worldwide is more crucial than ever with the increasing number of passengers. This study examined the concept of TDM methods, explicitly focusing on their impact on traffic congestion and vehicle gas emissions. There are other ways to alter rush hour schedule choices, such as increases in gasoline taxes and emission fees. The researchers analyzed its impact on traffic congestion as a viable strategy to decrease the number of vehicles on the road and minimize fuel consumption [12]. Delay times are one of the main factors for determining the level of service that was studied in this research using an HCS program that had the LOS F [13]. In this study, the researcher evaluated the behavior of vehicles on the stop lines planned on the road surface and the extent of their impact on the intersection capacity [14].

The investigator's study focuses on Bangladesh City and provides an overview of the TDM strategy. This study examines TDM techniques in developing nations to tackle some of the most prevalent issues with transportation and traffic management (TTM) systems [15]. The current study looked at how putting connected vehicle (CV) technology into use at three types of interchanges would affect mobility: conventional, diverging, and single point (SPDI). A microsimulation environment built in VISSIM, along with ASC/3 software in the loop signal processors and Python-programmed vehicle-to-network communication methods, served as the foundation for the evaluation. The interchange design had a greater influence on traffic, as the researchers have demonstrated. Specifically, a 100% resulted in 6.4% fewer delays than a 0%, even without accounting for the impact of interchange design. [16]. The paper's primary objectives are to construct a "smart" signal controller using PTV VISSIM microsimulation software and to investigate and assess ramp metering situations on a motorway on-ramp. Because of the increased traffic volume, the researcher examined a section of Thessaloniki's Ring Road. From the start of a vehicle's journey to the end, its speed decreased by approximately 35%. This is a noteworthy decrease, and the actual service level was F [17]. In the VISSIM program, various actuation and adaptive signal control schemes for interchange networks are investigated. Many nations manage their signal controllers in a traffic-responsive manner, using tools such as Synchro, HCS, or Transit to optimize cycle times and green splits for fixed-time control. The signal head displays the green and red times. In the simulation, the signal head occupies the physical stopping bar. Research revealed that cars are randomly spaced out 0.5 to 1.5 meters apart before the signal stops [18].

The simulation platform simulates and examines the control latency at signalized interchanges and double lanes on a VISSIM modelling platform. Given the distinct needs of both vehicles, we independently measured and verified the capacity at each interchange approach for both car passengers and heavy vehicles. The simulation tests included signalized interchanges with variable ramp and arterial volumes, ramp spacing, and heavy-vehicle percentages. The control delay and level of service of the arterial approaches and off-ramp of roundabouts

and signalized diamond interchanges have been calculated and evaluated based on the simulation findings [19]. The researcher looks at the two options: right-of-way requirements, building costs, travel durations, and safety. It then suggests situations. The researchers studied isolated interchanges that were not connected to other interchanges because they noted that if there were adjacent interchanges with ramps on the right side, the left-hand exits and entrances connected to an interchange could lead to relatively inefficient and dangerous weave zones. Every possible combination of design and heavy-scenario vehicle was simulated. The investigation yielded lower average aggregate travel times for the four-level interchange at every ramp design speed. The savings varied from 0.7 to 2.4 percent, or from just 6 to 21 vehicle hours per hour of operation [20]. When planning a new road, the GIS program is one of the means of analyzing road problems in terms of capacity, vehicles, and gas emissions [21].

### 3. Methodology

In this study, the proposed methodology consists of six critical steps: Study area, data collection, VISSIM analysis program, traffic volume solutions, results, and conclusions.

#### 3.1. Case Study

Muaskar Al-Rashid is located in the southeastern part of Baghdad city. Commercial and industrial in the Al-Karrada and Zafaraniyah zones. The intersection comprises Al-Doura Expressway (east-west) and Tariq Bin Ziyad Street (north-south). The intersection consists of four approaches: Al-Zafaraniyah and Al-Karrada; each approach has three routes (L, Th, and R) and two service roads (E and F). The Doura Expressway (C) and the Baghdad al Jedida Expressway (D) have two routes (L and R). The bridges Th1 and Th2. There are also a lot of pedestrians, which leads to congestion. This area was studied in collaboration with Amant Baghdad. Fig. 1 shows Google Maps 2023 of Muaskar Al-Rashid interchange. The coordinates of the interchange are ( $33^{\circ} 17' 37''$  N  $44^{\circ} 27' 11''$  E).

##### 3.1.1. Basic geometry

Two types of data were collected from the field: geometric and operational data. The geometric data encompasses information on the number and width of lanes for each route, as well as the length and number of lanes, ramps, and turning and interchange configurations. To collect characteristic levels, the researchers conducted multiple site surveys. Equally divided by direction for the crossroads are two, four, and five lanes. The interchange's geometric measurements and features were collected utilizing the GIS program and the fundamental engineering design map that the Baghdad Municipality provided (Al-Karrada Municipality). Table 1 shows the dimensions of the interchange.



**Figure 1.** Muaskar Al-Rashid interchange (Google Maps,2023).

**Table 1.** Geometric characteristic Muaskar Al-Rashid Interchange.

Zone	No. of directions	No. of lane	Road width	Median
AL Karrada (A)	2	4	30m	4m
AL Zafaraniyah (B)	2	4	30m	4m
bridge (Th1 and Th2)	2	3	24m	2m
Doura and Baghdad A-Jedida (C and D)	1	2	8m	-
Service roads (E&F)	1	1	4m	-

##### 3.1.2. Data collection

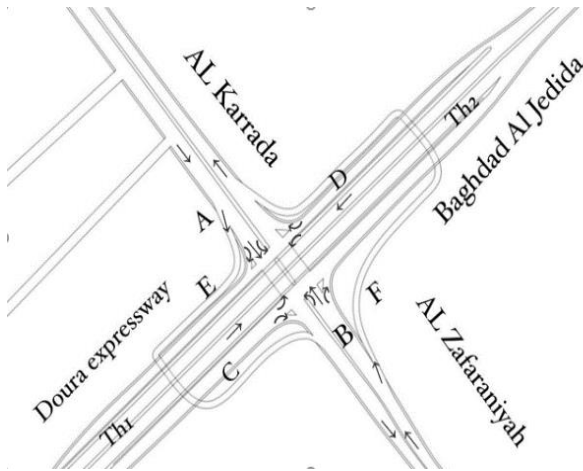
Traffic volume data was collected through video cameras, as Fig.2 focused on the interchange, with the support of the General Traffic Directorate. During (7:00 - 9:00 am and 1:00 - 3:00 pm) hours for three days in January 2023 (Sunday, Monday, and Wednesday).



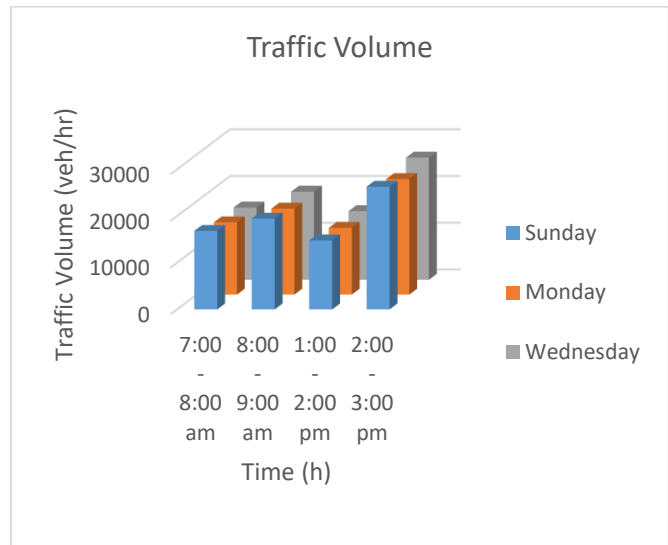
**Figure 2.** The Camera Room of the General Traffic Directorate.

Fig. 3 shows the routes of vehicles for each approach of the interchange, which consists of a four-way intersection, ramps,

and a bridge. One type of intersection was a single-point urban interchange, where all lines converged at a single point and were outfitted with bridges or tunnels as the principal lines of traffic movement. A single traffic signal controlled this intersection, and using a speedometer, a direct survey of vehicle speed was carried out at the interchange based on the kinds of vehicles. In the survey, a random sample of five automobiles was selected for every vehicle category. The survey's data findings show the traffic volume shown in Fig. 4.



**Figure 3.** The route movement of Muaskar AL Rashid interchange.



**Figure 4.** Traffic volume data for three days.

The peak hour for traffic volume is on the first day (2:00–3:00 pm). Heavy vehicles are prohibited from movement (trucks) between hours (7:00 am and 2:00 pm). They are allowed to pass through the interchange after 2:00 pm. Table 2 shows the traffic volume.

**Table 2.** Mauskar Al Rashid's traffic volume for Sunday.

Segments	Routs	7:00 –8:00 am	8:00 –9:00 am	1:00 –2:00 pm	2:00 –3:00 pm	HV %
Al Karrada	L	441	457	360	778	10%
	Th	407	434	409	723	7%
	R	269	398	380	513	8%
	E	95	135	137	291	0
Al- Zafaranyah	L	367	535	618	706	11%
	Th	360	470	493	673	8%
	R	253	368	385	539	12%
	F	81	124	186	327	0
Al Doura	L	285	323	253	389	6%
	R	344	382	259	457	7%
Baghad Al Jedida	L	298	399	376	450	7%
	R	386	391	316	476	9%
Al Doura expressway	Th1	6077	7975	5913	9902	22%
Al Doura expressway	Th2	7151	7053	4688	10048	20%
SUM		16814	19444	14773	26272	

**3.1.3. Current signalized diamond interchange procedures**

The operation of diamond interchanges is greatly influenced by three primary design components: interchange traffic patterns, interchange geometries, and signal control settings. The methods now employed to control traffic flows at diamond interchanges are briefly discussed below. Control the signal time for the Diamond Interchange. For diamond interchanges, there are two standard signal control configurations: the standard three-phase and four-phase signals. Signaling interchange diamonds ensures excellent coordination in every movement. (1) At the intersection, traffic turning left off the









ramp is given a green light; (2) Crossroads traffic proceeds through the intersection. Two restrictions apply to three-phase control. First, because the left turn volume and storage capacity determine each cycle, this procedure is only able to accommodate heavy left turns from arterials in one direction simultaneously. It is unable to accommodate high-volume requests from both off-ramps [5], [22], [23].

**3.1.4 Pedestrian crossing the interchange**

Pedestrians use the interchange extensively, crossing from all sides. The interchange lacks pedestrian crossing lanes and bridges, resulting in vehicle delays and increased risk of

pedestrian accidents. Controlled traffic signals should be installed at pedestrian crossings so that passengers with disabilities and those without disabilities can travel to the station more safely. There is also a way for pedestrians to cross to reach the station location in each configuration covered in this study [24]. The number of pedestrians at the interchange is 1413 for one hour, with pedestrians crossing without stopping, as shown in Fig. 5. The maximum average travel time is 74.26 seconds. Table 3 shows the results of the evaluation of the average travel time for the VISSIM program.

**Table 3.** Evaluate the average travel time for pedestrians for each leg.

Legs	Routs	No. of Pedestrians	average travel time (sec)
(A)		225	74.26
(B)		180	74.26
		212	
(C)		310	74.26
		90	
		110	
(D)		189	74.26
		96	

**3.2. Evaluate the Operational Level of the Interchange**

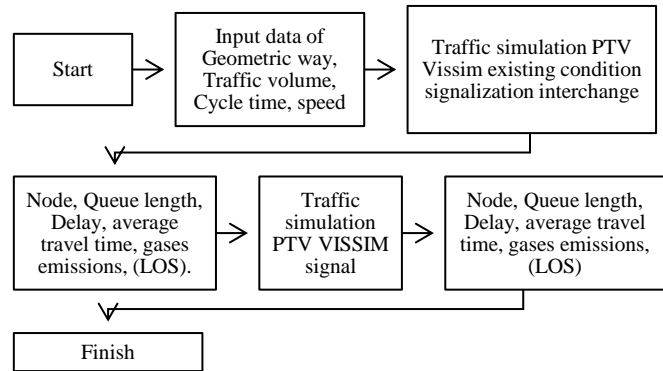
Traffic Simulation Using the VISSIM Program in assessing the level of service of road sections (LOS) in the VISSIM program, there are parameters such as vehicle behavior to be used in the traffic simulation modelling process, as shown in Fig. 6. The data listed previously were some of the inputs utilized to power a PTV micro-simulation program for Modeling. The raw data from the basic study VISSIM data input.



**Figure 5.** Pedestrian crossing coming from Link C.

Cycle time determines the efficiency of interchange, vehicle movement, and driver behavior. The overall lost time for each phase (start-up and clearance lost times) and the saturation flow rate have a significant impact on the accuracy of the traffic control model at signalized crossings. The extra time needed is known as "start-up lost time". This is the moment when vehicles begin to move in the lane as soon as the light turns green and

reaches free flow speed [14], [25], Al Karrada (north), Zafaraniyah (south), Baghdad al Jedida (east), and Al Doura (west). A cycle time that is too long may impact the intersection's performance, including wait times and delays. The calculated measure of the cycle time in the field for the four approaches was 720 seconds, so the red signals for Al Karrada and Zafaraniyah approaches were 515 seconds, the Baghdad Al-Jedida approach was 565 seconds, and the Al-Doura approach was 559 sec. Therefore, the delay time is so high, as shown in Table 4.



**Figure 6.** Phases of VISSIM modeling.

**Table 4.** Field results of the cycle time.

Phases	Approach	Time (sec.)			
		Green	Red	Amber	All Red
Phase 1	North	200	515	3	2
Phase 2	South	200	515	3	2
Phase 3	East	150	565	3	2
Phase 4	West	156	559	3	2
Cycle time (sec)					720

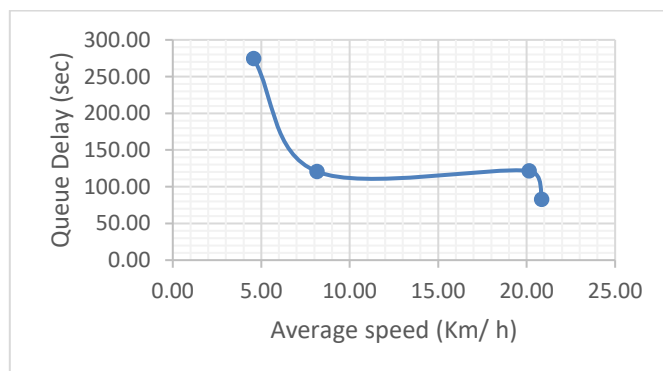
**4. Results and Discussion**

The modelling was based on some input parameters from the source data. The result in the node polygon incorporates interchange performance, showing parameter values. Some significant results were the LOS, vehicle delay, as shown in Table 5, the evaluation of the VISSIM program, queue length, and several parameters related to pollutants like NOx and CO, as shown in Table 6. Output characteristics are based on four conditional models. When applying the cycle length in the VISSIM program, a reasonable and appropriate cycle time of 320 s is entered. To be within the limits of programming time [26].

**Table 5.** Node evaluation results in the VISSIM program.

Segments	Routs	Average QLen Max(m)	Delay (sec)	LOS	Average travel time (sec)
Al-Karrada (A)	L	161.11	140.04	F	194.61
	Th	171	144.94	F	202.59
	R	12.20	59.92	E	88.83
	E	12.16	64.72	E	76.69
Zafaraniyah (B)	L	211.37	135.93	F	192.61
	Th	209.37	125.52	F	175.71
	R	44.20	76.7	E	97.97
Al- Doura (C)	F	44.16	46.28	D	93.63
	L	218.69	141.7	F	170.34
Baghad Al Jedida (D)	R	28.13	105.62	F	146.14
	L	245.64	167.71	F	358.1
	R	22.13	96.1	F	270.19

Results in Table 5 show that the level of service for Muaskar Al-Rashid is F, and the Delay is high due to the density of small vehicles and trucks crossing large numbers of pedestrians through this interchange, which affects the driver's behavior while the cars are moving. Fig. 7 shows that queue delay decreases with increasing speed.

**Figure 7.** The queue delay for all approaches to Muaskar Al Rashid interchange is significant.

Several steps were followed to produce a model that is appropriate for output and fits the requirements of this study. To form a network, the model was initially connected and then joined via connectors using VISSIM. The operational and geometric data that were collected in the field were used for this. The physical form of the network is finished by reflecting the geometric data. Connecting the dots was the initial step. It was utilized to simulate several signalized diamond interchange configurations and assess how well the base case conventional signal design performed operationally [27]. In five scenarios, suggested solutions are put into practice now and in five years at a 3% growth rate [28], assuming an increase in population and traffic volume. The amount of growth becomes 1.159. The result is multiplied by the current traffic volume, as shown in Table 6.

**Table 6.** The evaluation results of the VISSIM program.

Arm	parameters			LOS
	Queue Length (m)	Queue Delay (sec)	CO	
Al- Karrada (North)	253.79	120.57	361.1	F
Zafaraniyah (South)	235.20	82.59	566.4	F
Baghdad Al - Jedida (East)	189.44	274.60	116.4	F
Al- Doura (West)	104.97	121.57	191.5	F
SUM	783.42	599.33	1235.6	F

#### 4.1 Proposed construction of a tunnel in the north-south direction

One type of road intersection that is frequently seen is the diamond interchange. Most diamond interchanges were designed with unsaturated traffic circumstances in mind. As traffic tends to become saturated[29]. Design of a two-way tunnel, each direction with two lanes, wide 20 m, and a length of 470 m, and traffic volume for cars with front and service lanes (E, F) passing through one tunnel lane for the approaches to Karrada and Zafaraniyah. An HCS program was used to choose the appropriate cycle length to improve the traffic signal. The improvement cycle time signal was assumed to be 80 - 150 seconds, so the output was 128 s. The model applies current and future traffic volume.

The Table 7 results of the first scenario show that by constructing a tunnel and cancelling the traffic signal, the forward movement of the Al-Karrada and Al-Zafaraniyah approaches has a role in improving the level of service for the interchange from F to B for modification condition and C future condition, with the LOS improving for the left movements of approach (A) improving from F to C, as well as approaches (B) and (C) improving LOS from F to D. Approach (D) becomes E. There is an improvement in the queue length of vehicles for the current traffic volume, a decrease of 82%, and the future volume, which decreased by 64%. There was an improvement in queue delay modification conditions, a reduction of 91.4%, and future conditions of 81.1%, resulting in an average delay improvement.

**Table 7.** Results of Queue Length, Queue Delay, average Delay, CO, and LOS.

Conditions	Parameter				
	Queue Length (m)	Queue Delay (sec)	Average Delay (sec)	CO (g)	LOS
Existing	783.42	599.3	97.72	1231	F
Modification	139.53	51.5	19.82	1156	B
Future	282.47	112.7	28.30	1498	C

#### 4.2. Interchange alternative geometry design proposal

Three high, one medium, and one low traffic flow situations are among the several scenarios that are considered. The DDI's performance is evaluated at high flows exceeding the capacity of a regular diamond. The HCS program provides the ideal signal configuration and design for conventional diamond interchange. Additionally, VISSIM simulates pedestrian movements for a 4-lane DDI [30], [31]. In this scenario, building a bridge on the right side of the approach to Baghdad Al Jedida is proposed, with two lanes in one direction and a width of 7.5 m and a length of 900 m, passing over the Doura highway bridge down towards Al-Zafaraniyah. With the construction of the tunnel between the Zafaraniyah and Karada areas, we are canceling the traffic signal for the left route of the Baghdad Al Jedida approach, leaving three traffic signals for the other approaches as shown in Fig. 8, and imposing an improvement of the signal according to the HCS program cycle time of 133 s and an increase in speed. The output results are shown in Table 8. In this alternative, the scenario results show an increase in the overall service level from F to B when applied to the current scenario. Specifically, the tunnel route was 99.7% and 99.2%, and the R route was 92.4% and 74.2%. For approach Doura (C), route L was 65.4% and 64.5%, and route R was 68.6% and 66.1%. As for the approach to Baghdad Al Jedida

(D), the design of a bridge for left movement, and the cancellation of the traffic signal, the improvement rate. The new bridge was 100% LOS A, and route R was 99.8% current and 99.5% future traffic.



**Figure 8.** An alternative geometric design for interchange by using the VISSIM program.

**Table 8.** Results of delays and LOS.

Segments	Routes	Modification Condition		Future Condition		Existing Condition	
		Delay (sec)	LOS	Delay (sec)	LOS	Delay (sec)	LOS
Al- Karrada	L	43.84	D	54.07	D	140.04	F
	Tunnel	0.48	A	1.16	A	144.94	F
	R	22.85	C	34.36	C	59.92	E
Al- Zafaraniyah	L	38.22	D	51.64	D	135.93	F
	Tunnel	0.32	A	0.97	A	125.52	F
	R	5.82	A	19.76	B	76.7	E
Al-Doura	L	49.06	D	50.24	D	141.7	F
	R	33.17	C	29.83	C	105.62	F
Baghad Al Jedida	New bridge	0.03	A	0.04	A	167.71	F
	R	0.15	A	0.45	A	96.11	F

#### 4.3. A new geometry interchange and reversible lane design

Reversible lanes have been employed as a lane management technique to accommodate varying volumes on approaches according to the time of day. In various highway infrastructures (such as motorways, arterial highways, bridges, and tunnels), reversible lanes have been successfully used to boost peak traffic flow for a variety of traffic flow scenarios, such as inbound or outbound traffic, after-event traffic, and high-occupancy vehicles [22]. In this scenario, 200 metres from the Al-Zafaraniyah and Al-Karrada approaches, a U-turn is designed to allow vehicles to change their lane. It is proposed for the Al Doura approach to change the left route so that cars can drive on the right path and pass through the designed U-turn

linked with the Karrada Tunnel (Fig. 9). Therefore, the traffic signal for both movements will be cancelled to speed up the time for the traffic signal for the left movements as they approach Karrada and Zafaraniyah. Assuming an improvement in the cycle time of traffic signal 103 s according to the HCS program, the green time for the Karrada approach is 45 sec, the Zafaraniyah signal is 50 sec, the yellow signal is 3 sec, and the all-red signal is 1 sec. The third scenario is also considered an effective proposal according to the results shown in Table 9, where the level of service future traffic volume, as all interchange routes are LOS A, but the Karrada approach (L) route was C and route (R) was B. Table 9 shows the results of the average stop delay, the average travel time, and a significant decrease in the average travel time for movements.

**Table 9.** Compare the results of the interchange.

Segments	Routes	Modification Condition		Future Condition		Existing Condition	
		average travel time (sec)	average stop delay (sec)	average travel time (sec)	average stop delay (sec)	average travel time (sec)	average stop delay (sec)
Al- Karrada	L	52.42	15.99	73.48	33.27	194.61	117.16
	Tunnel	27.11	0	27.15	0	202.59	120.74
	R	29.18	5.81	43.15	18.98	88.83	41.84
Al- Zafaranyiah	L	53.04	11.73	53.06	12.04	192.8	116.67
	Tunnel	27.7	0	27.9	0	175.71	110.15
	R	28.37	0.24	29.38	0.34	97.97	62.53
Al-Doura	U-turn (L)	61.28	0.01	61.54	0.01	170.34	133.18
	R	27.46	0	27.54	0	146.14	98.41
Baghdad Al-Jihad	U-turn (L)	50.95	0.29	51.37	0.76	358.1	140.41
	R	25.2	0.14	25.83	1.16	270.19	73.12

**Figure 9.** Reversible Lane Design using the VISSIM program.

#### 4.4. Movement of each phase together and proposal using a Bus Rapid Transit

The Bus Rapid Transit is a modern means of rapid transportation consisting of 85 seats used in various parts of the world to reduce the use of small vehicles, gasoline consumption, and gas emissions [32]. Additionally, segregated lane BRT is wholly isolated from other traffic via tunnels or tall buildings. This particular BRT system provides a quick running speed compared to other bus services and BRT systems [24]. Suggested BRT route back and forth when passing through the tunnel between the two approaches, Al Karrada and Zafaranyiah. Control the traffic signal by the movement of the two opposite traffic lights, assuming that the green signal is activated for the left movements approaching Al Karrada and Zafaranyiah together. Then the green signal is activated for the left movements approaching Al Doura and Baghdad Al Jedida together. A field survey of 100 passengers who agreed to use rapid transit found that 50% agreed and encouraged this proposal. Assuming that the traffic signal improved according

to the proposal (80–150 sec), according to the HCS program, the cycle length improved by 118 s. The results of this scenario are shown as follows: KPIs, as shown in Table 9, Q Len Max, Average Travel time (s), and LOS

For this scenario, as shown in Table 10, there is a significant improvement in the LOS from F to B and a decrease in the total average travel time by 77.9% when applying the scenario for the current volume and by 76.8% for the future traffic volume.

**Table 10.** Compare the existing results with the results of the scenario.

Conditions	Q Len Max	Average Travel time (s)	LOS
Current	1348.79	2067.41	F
Modification	449.11	456.48	B
Future	511.51	478.73	B

Fig. 10 shows the vehicle queue delay of the scenario for each approach. The results of the collection data approach C for the current and future size are 94% and 93%, respectively. The approach B results in 92% and 91%, respectively. As for approach D 93 % and an approach only got close to 89% and 87%.

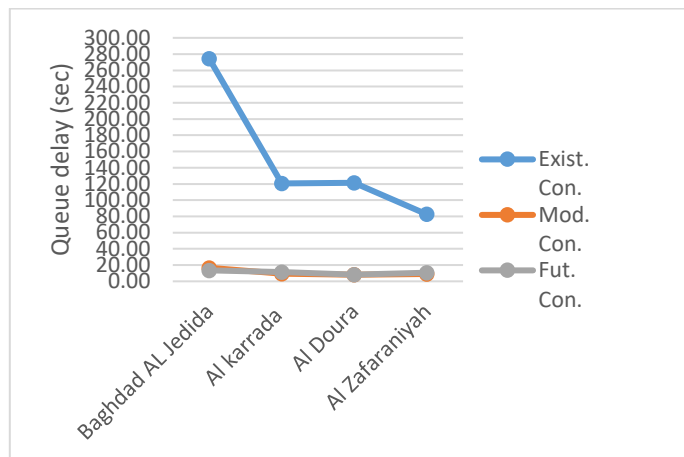


Figure 10. The queue delay for the interchange.

#### 4.5. Travel demand management (TDM)

Effectiveness in addressing TDM issues and objectives. The objectives are to improve awareness of the negative social and environmental repercussions of driving, encourage people to use the most practical means of transportation for their journey, and encourage drivers to rely less on their cars. TDM's primary goal is to reduce the number of vehicles on the road network while providing a wide range of options for individuals who choose to travel [33], [34]. One hundred passengers in single and multiple cars participated in the fifth scenario (TDM) study survey about using buses. 50 samples representing single-occupant vehicles and 50 samples representing multi-occupant vehicles. A field survey form with a long list of questions (driver's gender, age, whether he prefers to use public transportation, economic savings, and Delay). The data indicates that 28% of women and 72% of men ride autos.

Additionally, there were 28 drivers between the ages of 18 and 30, 39 drivers between the ages of 31 and 45, and 33 drivers between the ages of 45 and 60. Half the drivers said they would rather take public transit, while the other 50% disagreed. To generate analytical results, multiply the 50% ratio of those who consented to use buses by the present and future traffic volume, omitting heavy autos, and apply the resultant number to the PTV VISSIM program. The amount of cycle time improvement hypothesized by the HCS program is 128 s. The last scenario, TDM, is considered one of the practical scenarios for improving the service level from F to C and D for the current traffic volume and after five years. Table 11 shows a decrease in the average vehicle delay (sec) rate by 70.7% and 64.1%, respectively. The average stopped Delay (sec) decreased by 88.7% and 85.5%, respectively. Total average travel time decreased by 67.3% and 64.5%, respectively. Fuel consumption has increased due to the increase in vehicle speed and, thus, the burning of fuel by engines.

Table 11. Scenario results comparison.

Analysis	Average Vehicle Delay (sec)	Total average travel time (sec)	Average Stopped Delay (sec)	LOS
Current	97.72	2067.39	82.17	F
Modification	28.55	674.1	9.24	C
Future	35.08	733.58	11.84	D

Fig. 11: Average travel time for the distance traveled for all approaches to the interchange by VISSIM simulation.

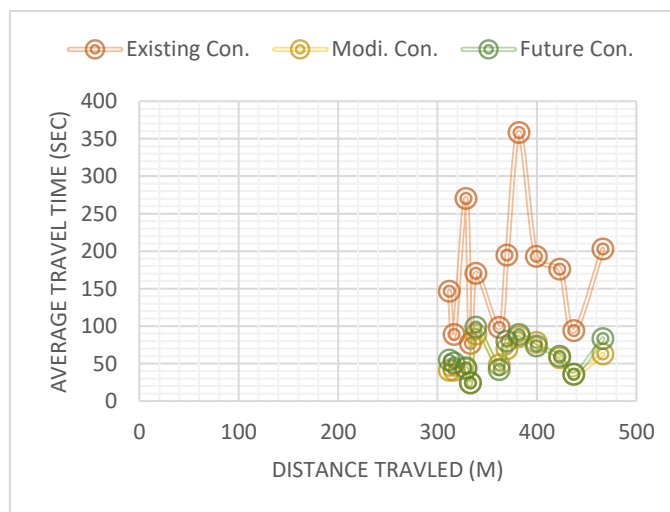


Figure 11. Average travel time for the current and future traffic volume scenarios.

#### 4.6. Discussion

The proposed traffic control approach aims to identify the interchange problem by collecting data and evaluating it using the VISSIM program. The results indicated a need to reevaluate the interchange and propose a suitable model to reduce vehicle delays. Solutions were therefore targeted as proposals to improve interchange. The tunnel design of the first proposal is efficacious in improving the level of service for the interchange from F to B and C, reducing the average Delay by 79.7% for the current traffic volume and 71% for the future traffic volume. The second proposal, regarded as one of the finest and implemented in numerous international interchanges, resulted in a shift in service level from F to B at the current interchange and LOS C at future times. The third proposal, which focuses on altering the route movement and improving the LOS from F to A at present and to B in the future, is deemed more cost-effective and quicker to implement than the second proposal. Many countries have begun to activate the BRT, a modern means of transportation that can significantly reduce congestion, as one of the most effective solutions. When traffic signals are controlled, the level of service improves from F to B, and the average travel time decreases by 77.9%. The scenario accounts for the current traffic volume, and it increases by 76.8% for future traffic volumes. The Ministry of Transport could implement the transport management policy

immediately, given its proven effectiveness and economy. After five years, the last scenario, TDM, is considered one of the most effective scenarios for improving the service level from F to C and D for the current traffic volume. The average vehicle delay rate (sec) decreased by 70.7% and 64.1%, respectively. The stopped delay average (sec) rate decreased by 88.7% and 85.5%, and the total average travel time decreased by 67.3% and 64.5%, respectively. Fuel consumption has increased due to the increase in vehicle speed and, thus, the burning of fuel by engines.

## 5. Conclusions and Recommendations

This study explains the performance evaluation of the Muaskar Al-Rashid Interchange using the VISSIM program, following the identification of a need to increase road capacity to manage the traffic volume and congestion.

This study presented five ideal remedies to the Queue length interchange brought on by cars using the on-ramps to go to the Mauskar Al-Rashid. Every answer is examined using the matching structure. Building an intersection with the VISSIM model of actuated signal control is simple. Cost is a crucial consideration when constructing or carrying out a project. Besides the essential elements shared by all BRT lane configurations, more research on the dynamic reversible lane design is necessary (especially for assessments). However, there are operational gains when using the new design in certain circumstances with large volumes.

It is not advised to use this dynamic reversible left-turn design only for some diamond interchange scenarios, but rather for large entry volumes that include significant left-turn flows. Its use could significantly reduce travel time and increase interchange throughput. These findings are limited to the chosen geometry and simulated and modelled traffic situations. Lastly, this evaluation of a novel design approach using theoretical Modeling still requires practical implementation.

The first proposal is efficacious in improving the level of service for the interchange from F to B and C and reducing the average Delay by 79.7% for the current traffic volume. The third proposal, which depends on changing the movement of routes and the LOS improvement from F to an A at the current and B in the future, is considered more economical.

Recommendations include studying other interchanges in the capital, Baghdad, due to the stifling crowding, and using modern analysis programs in a broad and detailed manner. In the study area, a pedestrian bridge is preferred because it appears to be safer than a crosswalk, while a crosswalk with traffic signal control is better than one without.

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## Conflict of interest

The authors declare that there are no conflicts of interest regarding the publication of this manuscript.

## Author Contribution Statement

Dr. A. Subhi contributed by conceptualizing the idea, summarizing the main concepts, planning, and supervising the work. T. Sameer drafted the manuscript, collected data, analyzed it using (GIS, HCS, and VISSIM) software programs, and proposed solutions. Dr. A. Abbas contributed to monitoring the data.

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