ZANCO Journal of Pure and Applied Sciences
The official scientific journal of Salahaddin University-Erbil
https://zancojournals.su.edu.krd/index.php/JPAS

ISSN (print):2218-0230, **ISSN (online):** 2412-3986, **DOI:** **http://dx.doi.org/10.21271/zjpas**

RESEARCH PAPER

Diagnosing of Black Spot Signalized Intersection in Erbil Street Network

Abdulhakim Othman Salih kozapanky[1]
[1]Department of Civil Engineering,College of Engineering, Salahaddin University-Erbil, Kurdistan Region, Iraq

A B S T R A C T:
Road safety is highly relevant in today's societies as vehicle accidents claim lives every day. Intersections are especially prone to crashes which lead to the worst outcomes. Usually, accident hotspots are places in which there is a probability of high risk or accident occurrence**.**

Accident black spots can be intersections, road sections and other areas which can refer to different contents. One of the most cost-effective road safety interventions is to eliminate so-called black spots, that is, to remedy accident-prone locations along the road. Signalized intersections in urban areas tend to involve more risk than other types of intersections. It is important to diagnose the cause of the problem before developing potential countermeasures**.** Diagnosis often involves a review of the crash history, traffic operations, and general site conditions.

The purpose of this paper is to investigate a high accident signalized intersection in the city of Erbil then to apply the procedures of Highway Safety Improvement Program (HSIP), also the Positive Guidance Procedures initiated by the Federal Highway Administration (FHWA), was completely executed on the above location.

The study characterized the accidents, diagnosis , field conditions, then found the contributory factors to the accidents and finally suggesting countermeasures that if applied can increase safety to a considerable amount

This study will help transportation planners to understand the factors causing accidents and take appropriate measures to reduce the casualties in the intersection construction planning stage and existing conditions. Thus, it gives an idea to take appropriate action to reduce accidents in the short term and over a long period of time.

KEY WORDS: Accident Counter-measures, Accident Patterns, Black Spot Intersections, Diagnosis, Highway Safety Improvement Program, Intersection Safety.
DOI: http://dx.doi.org/10.21271/ZJPAS.35.6.5
ZJPAS (2023) , 35(6);38-58.

1. INTRODUCTION:

Road traffic safety is a world-recognized traffic problem, as vehicle accidents claim lives every day. According to the findings of the World Health Organization (WHO), road traffic accidents are the eighth leading cause of death worldwide. (WHO, 2018, Wan,Y.,et.al.2021) The main factors involved in road accidents are road, vehicle, and human factors (drivers) (Mishra,A.,et.al.,2022).

Traffic safety researchers and stakeholders should consider all the critical factors, and measures should be taken to prevent road accidents and increase road safety(Hussain,M.,et.al.2021).Road accidents cannot be totally prevented but by suitable traffic engineering and management the accident rate can be reduced to a certain extent. For this reason systematic study of traffic accidents are required to be carried out. The proper investigation of the cause of accident will help to the propose preventive measures in terms of design and control. (Singh S.,Patel S. S.,2020).Recently, researches has revealed that road crashes causing severe injuries have been

* **Corresponding Author:**
Abdulhakim Othman Salih kozapanky
E-mail: kandinawa57@yahoo.com
Article History:
Received: 05/02/2023
Accepted: 30/04/2023
Published: 15/12/2023

identified as a significant public health issue. Hence, stringier countermeasures should be initiated to reduce the number of road crashes that cause severe injuries.(Bin Islam,M.,Kanitpong,K.,2008 , Athiappan,K.et.al.,2022).

Intersection safety studies are essential because traffic intersections are especially prone to crashes which lead to the worst outcomes. (N.H.T.S.Administration *et al.*, 2010,Mishra,A.,et.ai.,2022). According to the U.S. Department of Transportation (USDOT), more than 50% of road crashes leading to fatality or injury happen at or near traffic intersections. (Mishra,A.,et.al.,2022,FARS,2022) Road accidents at intersections can be attributed to a combination of different factors like humans (drivers, riders, vehicle occupants, pedestrians, tri-cyclists, and bicyclists), vehicles (design or structure, weight, equipment like seat-belts or tires), and infrastructure or environment (road design, signage, weather, conditions affecting visibility)(Hagenzieker,M.P.,2014,Prieto,F.,2014,Azadeh,A.,2016). These factors lead to black spots - places where road traffic accidents have historically been concentrated (M.Ghadi,A.Torok,2019,DebrabantB.et.al.,2018,SandhyavitriA.,2016). However, there is no standardized approach that can be followed for all types of roads. (M.Ghadi,A.Torok,,2017,Roy,D..et.al.2019)

Signalized intersections in urban areas tend to involve more risk than other types of intersections. A focus on signalized intersections, such as countdown timers, signal retiming, enforcement lights, curb extensions, etc. would have an impact at these crashes.(Kononov,J,Janson,B.N.,2002,HSIP,2018).

Usually, accident hotspots are places in which there is a probability of high risk or accident occurrence,(Hss,2020,Shafabakhsh,G,Saj,Y.2022), these spots are usually found in certain areas of the road, such as crowded intersections and sharp curves.

Recognizing the safety problems and the importance of reducing them, highway safety authorities have established Highway Safety Improvement Programs (HSIPs), which the objective of these programs is to identify accident prone locations, which have abnormally high accident occurrence, and implement appropriate and effective countermeasures in order to improve the safety potential of these locations.(Sayed,T.1997&Sayed,T.et.al,1997,RITSP,2001). It comprises three components: planning, implementation, and evaluation. (HSIP, 2016, FHWA, 2017).

The Highway Safety Manual (HSM) outlined the Roadway Safety Management Process, which includes six components as shown in **Fig.1**.(Tsapakis,Iet al.,2017andAASHTO,2010)It seems that diagnosis and countermeasure selection-following network screening-,are the second and third processes, respectively, of the general safety management framework.(Tsapakis,I et al.,2017) Diagnosis is the process of further investigating the sites and issues identified from network screening. (FHWA, 2017)

According to the HSM, (AASHTO,2010,FHWA,2014,Herbel,S.et.al.2010) the diagnosis process includes three major activities: 1. Safety data review, 2. Assess supporting documentation, and 3. Assess field conditions.

The purpose of the diagnosis process is to develop a basic understanding of crash patterns, causes of collisions, and existing roadway characteristics at high risk sites that were identified from network screening. The knowledge gained from diagnostic activities can be used as the foundation for selecting appropriate countermeasures that have the greatest potential to address the safety problems and needs at each site examined.(FHWA,2016Tsapakis,I et al.,2017)

The output of the diagnosis phase is a set of applicable countermeasures for each accident prone location and the degree of belief in each countermeasure.

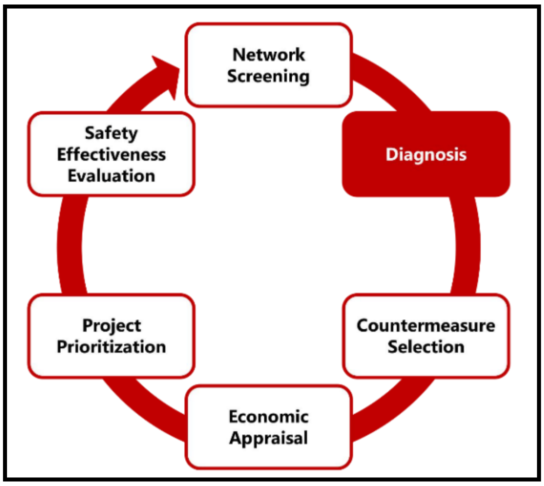

Figure 1: Schematic. Roadway Safety Management Process(AASHTO, 2010)

2. STUDY PROGRAM

The present study includes the complete diagnosis and site investigations to the location criticized as hazardous from the hazardous locations identified in Erbil street network. A problem location was selected in this diagnosis phase and the **Positive Guidance Procedures** initiated by the Federal Highway Administration (FHWA**) (**FHWA, 2017**)**, was completely executed on this location.

Positive Guidance is an approach to enhance the safety and operational efficiency of hazardous locations. This approach joins the highway engineering and human factors technologies to produce an information system matched to the characteristics of the location and the attributes of drivers. The Users' Guide to Positive Guidance is used to both analyze the location and develop the most effective solution. The Guide provides a procedure consisting of six major functions: Data collection at problem locations; problem specification; definition of driver performance factors; definition of information system requirements; determination of positive guidance information; and evaluation.(Herbel,S. et al..2010, Gerson J.A&Harold, L., 2009)

The Positive Guidance consist of six procedures, five of them were applied as a (**Before Study**) stage of the site investigation and the safety improvements proposed were depend on the above five procedures. The sixth procedure in the main Positive Guidance, represents the (**After Study**) stage which should be executed after implementing the safety improvements suggested in the study for the location.

The Makhmur Signalized Intersection located on Peshwa Qazi Ring Street which crossing Makhmur radial street in Erbil street network, was criticized as hazardous intersection spot in Erbil street network according to the high accident location identification program considered in this study.

Location map for Makhmur intersection is shown in **Fig. 2.** (https://www.google.com/maps). This Intersection has long been criticized as a hazardous location by the public and media and it was clear that, many trials were initiated to correct this location after the occurrence of each accident, but the danger is still there.

The above location was deeply analysed to show the procedures should be followed to diagnose the other hazardous spots (identified and candidated for more site investigations), for better safety corrections and to reduce their accidents in the future.

The Statistical Package for the Social Sciences (**SPSS**),version 29**(**SPSS,2022**)** software was utilized to analyse the data collected at the hot site-accident spot- as the micro level factors causing the accidents, such as: traffic& geometrical characteristics, driver& human behaviour, type of collision, location furniture, and environmental factors.

Different functions of the positive guidance procedure to decide the optimum safety improvement requirements for it can be summarized as follows:

Figure 2: Intersection Location Map(https://www.google.com/maps)

3. POSITIVE GUIDANCE PROCEDURES

3.1. Data Collection (Function A)

First activity always in the positive guidance procedure is to review existing information, and data to become familiar with the safety, and operational aspects of the site. Data in this case were accident records, traffic studies and diagrams, video filming, geometric design layout details and complaints from traffic officials and the public. Traffic, geometric data and video filming were collected and recorded during the field survey which carried out by this study.

The geometric design site map prepared also by the present study through the field survey work, and found quite useful in the final safety improvement design proposed.

Accident details were obtained from the same accident data collected for the identification and ranking hazardous locations .This intersection was found as one of the worst intersection in which accidents tried to cluster during the three years of study between (2020-2022). 54 recorded accidents occurred on this intersection during this 3 years period.

Accidents are plotted on collision diagram in **Fig. 3.** As shown from the collision diagram, the right angle collisions are the dominant type (22 of 54 accidents) and nearly all the accidents occurred under dry weather conditions due to vehicles at high speed and without care to traffic signals. Details of accident analysis by type of collision are shown in **Table 1.**

Accident data from the accident reports summarized were analysed generally in order to become familiar with the accident characteristics, and any particular trends which might lead to the identification of specific problems. Through the analysis of the collected accident data related to this worst intersection, by the aid of Crosstabs Subprogram in the (**SPSS**) computer package **(**SPSS, 2022**)**, the various cross relations were carried out such as: **Table 2** summarizes the analysis of accidents by hour and other important relating variables during the study period, in which morning and afternoon peak involvements are shown. The highest number of accidents noticed at (7:00) and (8:00) a.m. (7 & 5 of 54) accidents respectively and at (12:00) and (14:00) p.m. (7 & 6 of 54) accidents respectively, which the total four peak hours was (25 of 54) accidents. **Table 3** shows the analysis of accidents by month of year, in which the highest number on May and December (9 & 8 of 54) accidents respectively.

Road accidents are relatively higher in May, July and December, which reveals that extreme weather (highest in May-July and lowest in December) is responsible-beside of other factors- for increasing the number of accidents. There are certain psychological and physiological effects of high temperatures on drivers. Emotions arise with the temperature, people are more irritable to others, get tired, undergo sleepy conditions, and finally, their reaction time gets slower (Singh S., 2017). The occurrence of accidents at low temperatures (December) is also relatively high. The reason associated with this fact is that the driver uses the heater when driving, and the warmer environment inside the car compared to the outside renders the driver drowsy. This drowsiness has a detrimental effect on road safety. (Hussain, M. et.al.2021)

Table 4 shows the analysis of accidents by day of week, Saturday and Wednesday were the largest (13 and 14 accidents of 54 respectively). The analysis of accidents by year are shown in **Table5**, and as shown the accidents at the last year were less than the two previous years. **Table 6** shows the analysis of accidents by type of accident in the study intersection and it is shown that nearly all accidents (52 of 54) accidents are dominant collision type, which resulted in (1) deaths, (43) injuries and (118) vehicles damaged during the study period. The analysis of accidents by severity is shown in **Table 7,** in which the Property Damage Only (PDO) accidents are the dominant type (36 of 54) accidents. Light condition accident analysis shown in **Table 8**, and it is shown that the dominant portion is the day time accidents (46 of 54) accidents, while the darkness accidents were (8 of 54) accidents.

A condition diagram showing lane width, geometric configuration, and locations of traffic control devices, is shown in **Fig.4**. Traffic data collected at this intersection during a.m., peak period on Saturday is shown in **Fig.5**.

Delay analysis, based on the highway capacity manual methodology and delay formula, with making use of present cycle time (79 sec) and traffic volume in each approach during the a.m. peak hour, results the average delay per intersection of (83 sec). This result indicates the high deficiency and low level of service (**LOS**) during peak hour demand. According to (**HCM)** the level of service was (**F)**, as the average stopped delay for vehicles was more than (60 sec.), while signalized intersections are designed on the basis of (**LOS)(B** or **C)** for urban intersections **(**HCM,2022**)**. Details of delay analysis are shown in **Table 9**. However discussions pointed to possible motorist information deficiencies on some approaches of this intersection. Directory geometrical information might be inadequate, and no geometrical improvements were implemented for this intersection.

Review of historical data pointed to the following areas for further investigations:

- Erratic maneuvers in the form of lane changes in the major street or close conflicts at the intersection in the shape of sudden stops, swerving … etc;
- Sight distance for the signals existed were checked;
- Speeds through the four approaches;
- Updating the location of traffic control devices noted on condition diagram;
- Present cycle time for the intersection and the portion of green time for each approach;
- Location and type of navigational, and guidance information were noted;
- Sight distance for channels were checked;
- Pavement surface condition was observed visually;
- Operations during Saturday a.m., and p.m. peak periods were observed;
- Sources of driver confusion were looked up; and
- Formation of queues on minor road approaches was noticed.

After collecting the historical data, driving throughs, video filming, and to collect more science about the indicators of the problem obtained from the historical data. Drive through and operation observations conducted in the morning and in the mid-afternoon on a week start days. Driving throughs were conducted on all approaches at posted speed limits of 40 km/h in both major and minor streets respectively. The following notations were made and summarized shortly in the field observation report with other explanation as shown in **Table 10**, some of them can be discussed in detail such as:

- Vehicles coming from the north and south directions on Makhmur minor street exceeded the speed of 40 km/h;

- Traffic control device locations were not exactly updated (see **Fig.4**);
- Navigational, and guidance information was confusing (this will be analysed in greater detail in later functions);
- Right lane on approach (D and C) from Peshawa Qazi and Makhmur Streets to the intersection were barricaded. this wasn't visible until reaching the first gore, also there is problem of stopping buses on the ends of the right turning lanes on Peshawa Qazi and Makhmur Streets;
- Asphalt pavement was not in good condition especially at approaches and right turn lanes, which there some type disturbing of the asphalt noticed in the shape of rutting and shoving;
- There are definite driver expectancy violations as well as some detection and recognition problems (these need more detailed analysis);
- Delays on the approaches were higher than usual due to improper signal timing and inadequate green portion for high volume of traffic on the streets (see **Table 9)**;
- Room is not provided for future development of the intersection for the change of its geometry from all directions;
- Poor marking, and considerable pedestrians volume; and
- **(LOS)** was low for traffic to operate in this intersection, especially at the minor approaches (see **Table 9**).

After completing drives through, the observer watched the traffic movements through approach (C) (from Makhmur Street). Conflicts within the intersection among vehicles from different directions of flow were recorded. The summaries of these conflict observations are listed in **Tables 11-14**, some notes and comments are given at the foot of each table that describes actual operations during period of observations. Based on the notations from drive through and operation observations there wasn't adequate evidence that some of the problem indicators could be alleviated by positive guidance program on this level of the analysis.

Based on the examination of the site via the historical data and observations, the following studies were made in order to provide additional problem characteristics:

- A drive through film was made of the site;
- Volume counts by lane and direction were made for a. m. peak period, as shown in **Fig.5;**
- Conflicts for different manoeuvres (turns, and sudden stops), were recorded for this intersection;
- Illegal movements through the intersection were recorded;
- Photos were made for all traffic control devices fixed in the intersection near approaches, (see **Fig.4**;
- Data from these studies were summarized for use in the analysis to be performed in the subsequent functions.

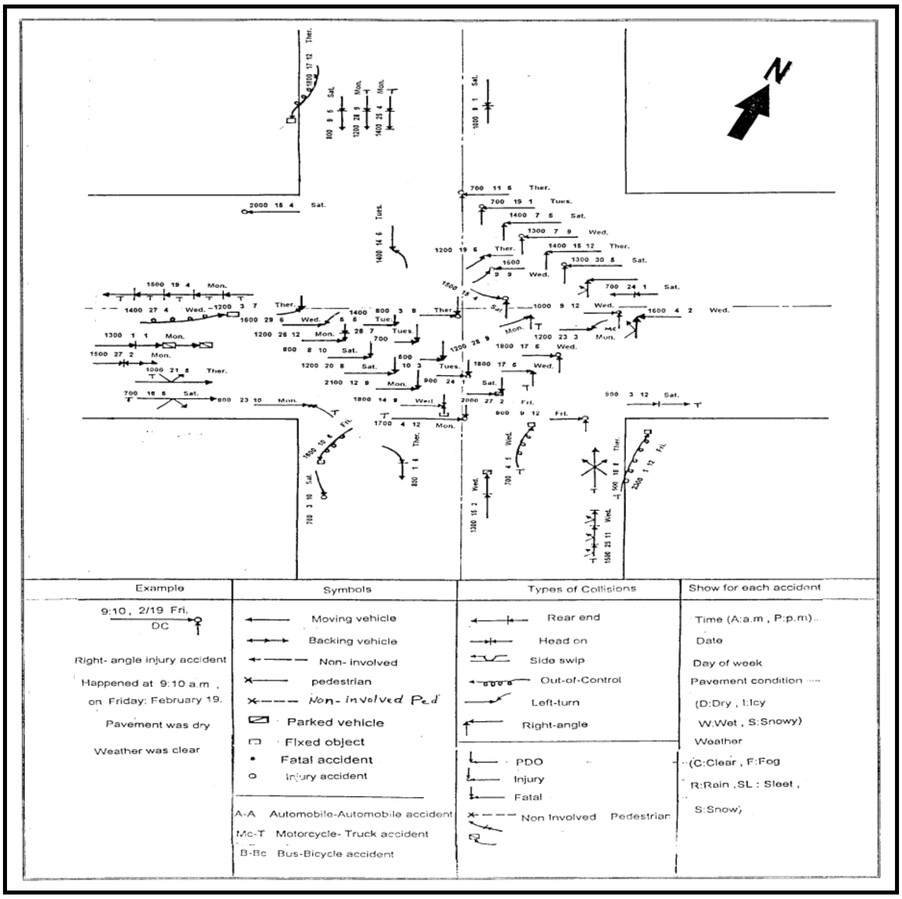

Figure 3: Collision Diagram

Table 1: Accident Analysis by Type of Collision

S. No.	Type of Collision	Accidents	
		Number	%
1	Right angle	11	20.37
2	Rear end	2	3.70
3	Head on	5	9.26
4	Sideswip	6	11.11
5	With fixed object	22	40.74
6	Leftturn	6	11.11
7	With pedestrian	2	3.70
Totals		54	100.00

Table 2: Accident Analysis by Hour During the Study Period (2020-2022)

Hour	Day of Month																										Total		Deaths		Injuries		PDO	
	1	3	4	5	7	8	9	10	11	12	14	15	16	17	18	19	20	21	23	24	25	26	27	28	29	30	No.	%	No.	%	No.	%	No.	%
500								1																			1	1.9			0	0.0	2	1.7
700		1	1						1				1			1				1				1			7	13			5	11.1	11	9.3
800	1	1				1	1												1								5	9.3			2	4.4	11	9.3
900		1					1								1					1							4	7.4			3	6.7	9	7.6
1000							2											1									3	5.6			1	2.2	7	5.9
1200		1														1	1		1			1		2			7	13			5	11.1	15	12.7
1300	1				1							1														1	4	7.4			4	8.9	9	7.6
1400				1	1						1	1									1		1				6	11.1			2	4.4	13	11.0
1500												1				1					1		1				4	7.4			1	2.2	13	11.0
1600			1				1	1																	1		4	7.4			5	11.1	9	7.6
1700			1																								1	1.9			1	2.2	2	1.7
1800											1			3													4	7.4	1	100	14	31.1	9	7.6
2000												1											1				2	3.7		0.0	2	4.4	5	4.2
2100										1																	1	1.9		0.0	0	0.0	2	1.7
2300	1																										1	1.9		0.0	0	0.0	1	0.8
Total	3	4	3	1	2	1	5	2	1	1	2	4	1	3	1	3	1	1	2	2	2	1	3	3	1	1	54	100	1	100	45	100	118	100

Table 3: Accident Analysis by Month of Year

Month	Total		Deaths		Injuries		PDO	
	No.	%	No.	%	No.	%	No.	%
1	5	9.3			5	11.1	11	9.3
2	4	7.4					10	8.5
3	2	3.7					4	3.4
4	5	9.3			3	6.7	11	9.3
5	9	16.7			4	8.9	18	15.3
6	6	11.1			6	13.3	12	10.2
7	2	3.7			0	0.0	4	3.4
8	3	5.6			6	13.3	8	6.8
9	6	11.1	1	100	16	35.6	13	11.0
10	3	5.6			2	4.4	4	3.4
11	1	1.9					6	5.1
12	8	14.8			3	6.7	17	14.4

Table 4: Accident Analysis by Day of Week

Week	Total		Deaths		Injuries		PDO		Light				Severity			Type		Year		
	No.	%	No.	%	No.	%	No.	%	Day	%	Night	%	Fatal	Injury	PDO	Runover	Collesion	2020	2021	2022
Sat	13	24.1			12	26.7	22	18.6	11	23.9	2	25.0		6	7	2	11	5	6	2
Sun	4	7.4			2	4.4	12	10.2	3	6.5	1	12.5		2	2		4	2	1	1
Mon	7	13.0					15	12.7	6	13.0	1	12.5			7		7	3	3	1
Tues	5	9.3			5	11.1	11	9.3	4	8.7	1	12.5		2	3		5	2	3	2
WED	12	22.2	1	100	23	51.1	30	25.4	12	26.1			1	4	7		12	5	5	2
Ther	7	13.0			2	4.4	16	13.6	6	13.0	1	12.5		2	5		7	2	2	3
Fri	6	11.1			1	2.2	12	10.2	4	8.7	2	25.0		1	5		6	2	3	1
Total	54	100	1	100	45	100	118	100	46	100	8	100	1	17	36	2	52	21	23	10

Table 5: Accident Analysis by Year (2020-2022)

year	Total		Deaths		Injuries		PDO		Light				Severity			Type	
	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%	Fatal	Injury	PDO	Runover	Collision
2020	21	38.9	1	100	22	48.9	44	37.3	19	41.3	2	25		6	14	2	21
2021	23	42.6			18	40	55	46.6	19	41.3	4	50	1	7	16		22
2022	10	18.5			5	11.1	19	16.1	8	17.4	2	25	1	4	6		9
Total	**54**	**100**	**1**	**100**	**45**	**100**	**118**	**100**	**46**	**100**	**8**	**100**	**2**	**17**	**36**	**2**	**52**

Table 6: Accident Analysis by Type of Accident

Type	Total		Deaths		Injuries		PDO		Light				Severity		
	No.	%	No.	%	No.	%	No.	%	D	%	N	%	Fatal	Injury	PDO
Runover	2	3.7			2	4.4			2	4.3				2	
Collision	52	96.3	1	100	43	95.6	118	100	19	41.3	8	100	1	15	36
Total	**54**	**100**	**1**	**100**	**45**	**100**	**118**	**100**	**46**	**100**	**8**	**100**	**1**	**17**	**36**

Table 7: Accident Analysis by Severity of Accident

Severity	Total		Deaths		Injuries		PDO		Light				Type	
	No.	%	No.	%	No.	%	No.	%	Day	%	Night	%	Runover	Collision
Fatal	1	1.9	1	100	8	17.8	3	2.5	1	2.2				1
Injury	17	31.5			37	82.2	33	28	15	32.6	2	25	2	15
PDO	36	66.7					82	69.5	30	65.2	6	75		36
Total	**54**	**100**	**1**	**100**	**45**	**100**	**118**	**100**	**46**	**100**	**8**	**100**	**2**	**52**

Table 8: Accident Analysis by Light Condition

Light	Total		Deaths		Injuries		PDO		Type	
	No.	%	No.	%	No.	%	No.	%	Runover	Collision
Day	46	85.2	1	100	8	17.8	3	2.5		1
Night	8	14.8			37	82.2	115	97.5	2	15
Total	**54**	**100**	**1**	**100**	**45**	**100**	**118**	**100**	**2**	**52**

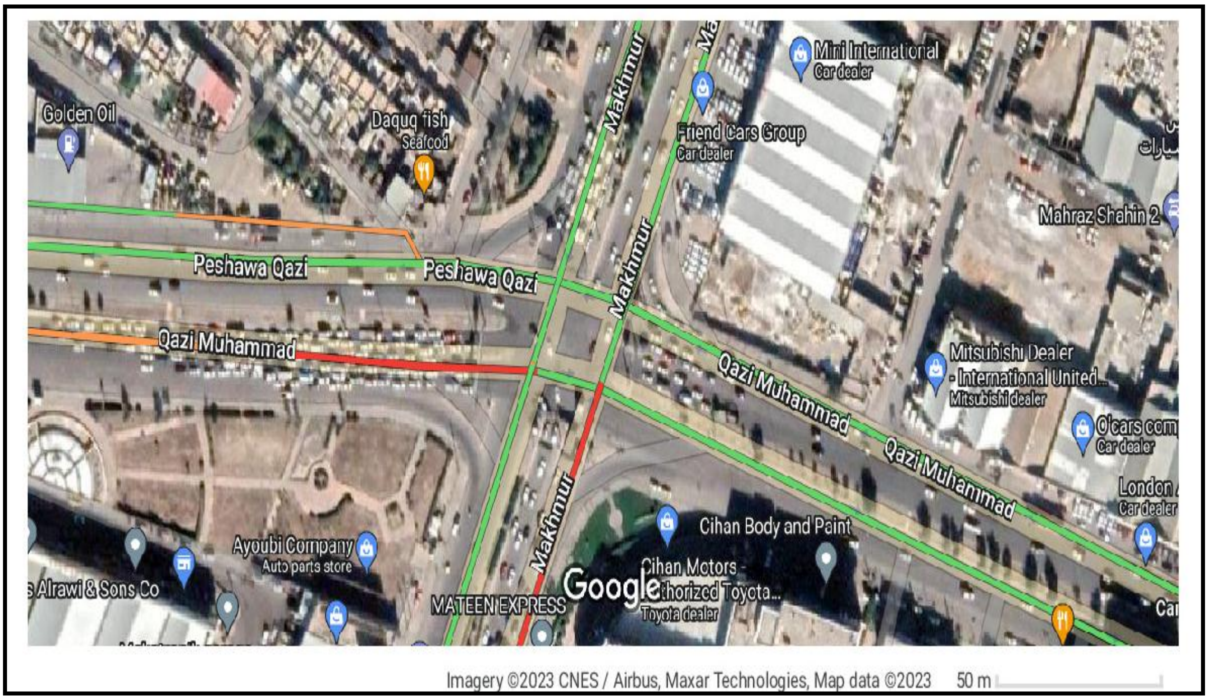

Figure 4: Condition Diagram(Makhmur Signalized Intersection)[https://www.google.com/maps]

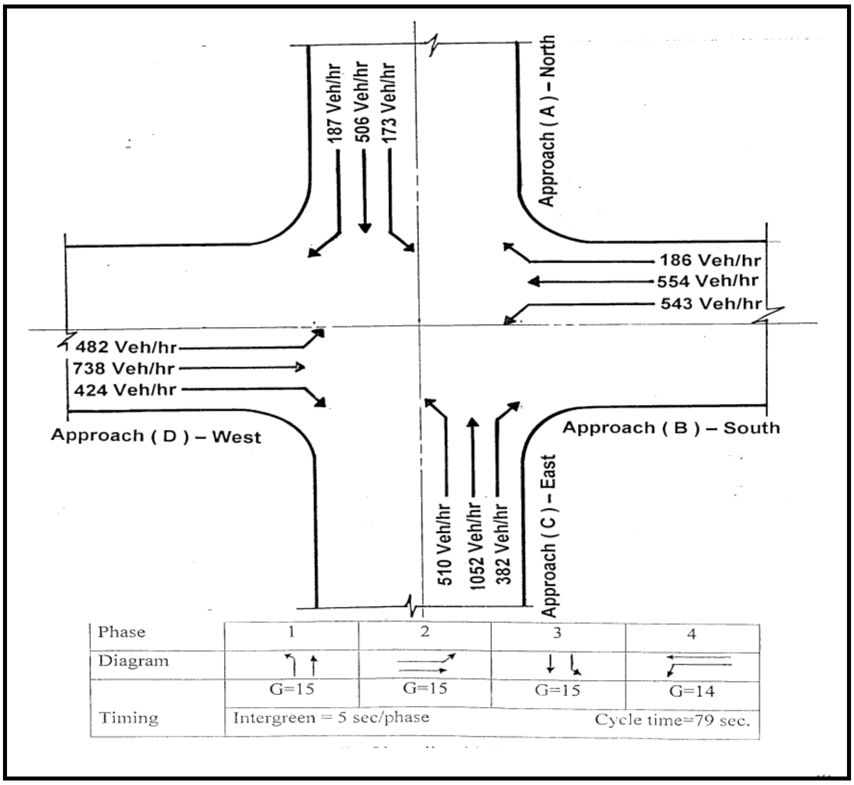

Figure 5: Intersection Approach Traffic Volume

Table 9: Delay Analysis based on Present Cycle Time

Delay Analysis												
Intersection Name	Present Cycle Time, C_o									HCM	Dav.	LOS
	App.	q	S	C_o	g	λ	X	C		Delay	Sec/hr	
Makhmur	N_{st}	506	5225	79	16	0.20	0.70	1058		23.70	83	F*
	N_l	173	1672	79	16	0.20	0.51	339		22.38		
	S_{st}	1052	7058	79	16	0.20	0.90	1429		29.19		
	S_l	510	1694	79	16	0.20	1.49	343		424.75		
	E_{st}	554	5403	79	15	0.19	0.54	1026		22.41		
	E_l	543	3458	79	15	0.19	0.83	657		29.38		
	W_{st}	738	3300	79	16	0.20	1.10	668		87.30		
	W_l	482	4950	79	16	0.20	0.48	1003		21.45		

* According to HCM, for Dav.>60 sec/hr.

LEGENED
q =Traffic demand - pcu/h.
C_o = Cycle time - sec.
X = Degree of saturation = q/C
g = Effective green time - sec.
λ= Green ratio = g/C_o
S= Saturation flow rate - pcu/h.
st= Straight thrugh lanes
C = Capacity of lane group (pcu/h) = S*g/C_o
HCM= Highway Capacity manual delay formula

Table 10: Field Observation Summary Report

FIELD OBSERVATION SUMMARY REPORT

LOCATION Makhmur Intersection

DATE 12-10-2022 (Saturday)

TRAFFIC CONTROL Signalized

TIME 8:30 A.M.

Design & Geometrics
- pavement width
- lane width(s)
- [X] pedestrian crosswalks and walkways
- [X] road condition
- shoulder condition and slope
- roadside slope/recovery area
- [X] guardrail
- [X] fixed objects
- channelization
- design speed (if one was used)
- driveways/alleys
- horizontal alignment (curves, superelevation)
- vertical alignment (humps, small hills)
- [X] bus stops
- recent changes

Traffic Controls
- [X] regulatory signs
- [X] timing of signals
- [X] traffic flow and movements
- [X] traffic conflicts
- parking allowed?
- [X] law enforcement
- [X] speed limit
- [X] pavement markings
- [X] route markers
- street name signs
- [X] guide signs
- [X] advance warning signs
- recent changes

Visibility
- [X] sight obstructions
- signs
- signals
- [X] markings
- [X] lighting
- reflectorization
- opposing traffic

Consider each item on the list as a possible cause of accidents. Check only problem areas, then explain each below.

1. High Speed on approaches;
2. Too much Conflicts;
3. Inproper Signal Cycle timing;
4. High delays at approaches;
5. Low level of service at P.H. demand,
6. Law Violations;
7. Faded pavement markings;
8. Bus stopping near the intersection at righ turn lanes cause sight obstruction, may be prevented or moved to far sides.

Prepared by Abdulhakim O. Salih

3.2. Specify Problems (Function B)

Analysis of each type of data (historical, site survey, observation, and performance) gathered in **Function (A)**, points to several different problems at all the intersection main approaches. Twelve site features were identified and classified as object, condition or situation hazardous. This number includes two inefficient operations based on traffic performance indices. **Table 15** lists these hazardous and inefficiencies which were subjectively ranked according to severity using a simple high, moderate, low scale.

3.3. Define Driver Performance Factors (Function C)

Some vehicle actions were recorded like; lane changes right, lane changes left, lane changes middle from both right or left, and sudden stops which most of them were conflicts observed and listed in **Tables 11-14**.

Although a large amount of manoeuvres were observed, but a considerable hazardous was due to stopping buses and vehicles on both west and south down streets of the intersection approaches (i.e. approaches A and D respectively), which causing problem for right turning vehicles coming from north to west, and west to south respectively and all straight and left turning streams which conflict with those vehicles and buses that changing lanes and paths to stop at the mentioned downstream approaches. For this analysis, it can be concluded that the problem was in these two positions for this reason a very detailed conflict analysis was performed for the driver performance at these zones.

Table 16 presents the results of expectancy analysis and **Table 17** presents the expectancy violation characteristics. **Table 16** describes the different features at the four intersection's approaches which give rise to the expectancy violations discussed before. Site features and driver response, which didn't involve expectancies or whose expectancies weren't violated. Entries in **Table 17** emphasize the information needs derived to alleviate the expectancy violations, and weather speed, path or direction are involved in the violation, and its solution. Latter indicators may be very important for use as evaluate criteria in **Function (F).**

Results of detection and recognition analysis are presented in **Table 18**. As shown from this table, three of the twelve hazard inefficiencies of the site discussed in **Table 19** were called out as having detection and /or recognition problems.

High traffic volume shown in **Fig.5** and inadequate cycle time offer the explanation of the relatively high frequency of conflict rates in **Tables 11-14** since the conflicts occurs in the same area.

Negative driving behaviour, which is inherently influenced by traffic circumstances and infrastructure, among other factors, is one of the leading causes of traffic accidents.**(**Mohsen, H. S., Moghaddam G. V. N.2020 , Shivani,S, Sebastian,S.,2019)

3.4. Define information requirements (Function D)

Based on the results of **Functions** (**B** and **C**), it appears that many of the site's problems occurs in the vicinity of the intersection area, as shown from the collision diagram (see **Fig.3)**, such as:

- Unexpected stops represented the most critical hazard partly due to the injury accidents at approaches (A and D**)** where crossing major and minor streets near these two approaches with small conflict area;
- Performance conflict data supported this point by showing that the two areas for the two previous approaches have the highest rate of conflicts (see **Tables 11-14)**;
- Performance conflict data for other two approaches (B and C) that cross traffic conflicts are also considerable between them and need elimination by more efficient operations; and
- Information load causing these conflicts was found on all approaches.

3.5. Define positive guidance information plan (Function E)

From the results concluded in **Function** (**D)** and to look for a better guidance plan for this hazardous intersection, data provided in **Functions** (**A**, **B**, and **C**), where compared with the **Manual on Uniform Traffic Control Devices** (**MUTCD)** requirements (warrants) for the installation of more efficient control in this location **(**FHWA, 2020**)** and due to the existence of traffic signals in this intersection, it was found necessary to redesign the cycle time length based on the following warrants, such as:

- Vehicular volume;
- Interruption of continuous traffic;
- Accident experience; and

- Combination of the above warrants.

Table 19 shows the delay analysis based on the proposed cycle time for the intersection and it is seen that how the proposed cycle time minimizes the total average delay to (43 sec.) and (**LOS)** is modified to level (**E**) according to (HCM) **(**HCM,2022**)**, by redesigning the cycle time(see **Fig.7**).

Fig.6 shows the final safety improvement design proposed to provide efficient control, sufficient capacity and (**LOS)** in this intersection for nowadays operations and future traffic. Some other important directionary, and warning signs are shown in the same Fig..

Table 11: Intersection Conflicts(Leg A)

INTERSECTION CONFLICTS

Location: Makhmur Intersection | Leg Number: A

Day: Saturday - Wednesday | Date: 10(19 - 23) - 2022 | Observer: Abdulhakim Othman Salih

COUNT START TIME (MILITARY)	TOTAL APPROACH VOLUME (vph)	Left Turn Same Direction		Slow Vehicle		Right Turn Same Direction		Opposing Left Turn		Left Turn From Left		Cross Traffic From Left		Left Turn From Right		Cross Traffic From Right		Right Turn From Right		All Same Directions		All Cross Traffic From Left		All Cross Traffic From Right		All Cross Traffic	
						Conflict-C						Secondary Conflict-SC															
		C	SC	C	SC	C	SC	C	SC	C	SC	C	SC	C	SC	C	SC	C	SC	C	SC	C	SC	C	SC	C	SC
8:30	920	2		6	3	24	8			6		8	1	16	4	12	1	18	4	32	11	14	1	46	9	60	10
																				0	0	0	0	0	0	0	0
10:30	740	1		4		14	7			7	2	6		12	1	8		16	1	19	7	13	2	36	2	49	4
																				0	0	0	0	0	0	0	0
12:30	830	1		3	1	13	1			4		6	1	13	1	10	2	12		17	2	10	1	35	3	45	4
																				0	0	0	0	0	0	0	0
14:30	890	4	1	8	2	19	12			6	1	7	3	19	7	22	5	19	3	31	15	13	4	60	15	73	19
																				0	0	0	0	0	0	0	0
Sub Total	3380	8	1	21	6	70	28	0	0	23	3	27	5	60	13	52	8	65	8	99	35	50	8	177	29	227	37
Totals		9		27		98		0		26		32		73		60				134		58		206		264	
Rates/1000 vehicle		2.7		8.0		29.0		0.0		7.7		9.5		21.6		17.8		0.0		39.6		17.2		60.9		78.1	

Sever Conflicts: Btween through from and all cross traffic from right (leg D)

Possible Causes of Slow Vehicle Conflicts: inadiquate cycle time, delays,and sight obstructions due to parking vehicles

Other Notes and Conflicts: Cycle time must be redesigned,prohibiting of stopping of buses and vehicles at approaches near the right turns, speed should be reduced, unavailability of lane markings

Table 12: Intersection Conflicts (Leg B)

INTERSECTION CONFLICTS																											
Location:Makhmur Intersection																				Leg Number: B							
Day: Saturday - Wednesday							Date: 10 (19 - 23) - 2022													Observer: Abdulhakim Othman Salih							
								Conflict-C						Secondary Conflict-SC													
COUNT START TIME (MILITARY)	TOTAL APPROACH VOLUME (vph)	Left Turn Same Direction		Slow Vehicle		Right Turn Same Direction		Opposing Left Turn		Left Turn From Left		Cross Traffic From Left		Left Turn From Right		Cross Traffic From Right		Right Turn From Right		All Same Directions		All Cross Traffic From Left		All Cross Traffic From Right		All Cross Traffic	
		C	SC	C	SC	C	SC	C	SC	C	SC	C	SC	C	SC	C	SC	C	SC	C	SC	C	SC	C	SC	C	SC
9:00	1250	8	2	12	1	2		1		24	6	18	3	11	1	13	4	22	8	22	3	43	9	46	13	89	22
																				0	0	0	0	0	0	0	0
11:00	971	3		6						17	2	10	2	4		6	1	14	4	9	0	27	4	24	5	51	9
																				0	0	0	0	0	0	0	0
13:00	952	2	1	5						13	1	8		6		7		16	6	7	1	21	1	29	6	50	7
																				0	0	0	0	0	0	0	0
15:00	923	5	2	13	3	2				19	5	22	7	13	2	11	1	20	12	20	5	41	12	44	15	85	27
																				0	0	0	0	0	0	0	0
Sub Total	4096	18	5	36	4	4	0	1	0	73	14	58	12	34	3	37	6	72	30	58	9	132	26	143	39	275	65
Totals		23		40		4		1		87		70		37		43				67		158		182		340	
Rates/1000 vehicle		5.6		9.8		1.0		0.2		21.2		17.1		9.0		10.5		0.0		16.4		38.6		44.4		83.0	
Sever Conflicts: Between cross traffic from leg C and right turn vehicles from leg A																											
Possible Causes of Slow Vehicle Conflicts: Delays and inadequate cycle time, sight obstructions due to bus and parked vehicles																											
Other Notes and Conflicts: Speeds are high, pavement markings are faded, pavement surface is disturbed at approaches, high percentage of trucks, and high percentage of cross traffic fromm leg C																											

Table 13: Intersection Conflicts (Leg C)

INTERSECTION CONFLICTS																											
Location: Makhmur Intersection																				Leg Number: C							
Day: Saturday - Wednesday							Date: 10 (19 - 23) -2022													Observer: Abdulhakim Othman Salih							
								Conflict-C						Secondary Conflict-SC													
COUNT START TIME (MILITARY)	TOTAL APPROACH VOLUME (vph)	Left Turn Same Direction		Slow Vehicle		Right Turn Same Direction		Opposing Left Turn		Left Turn From Left		Cross Traffic From Left		Left Turn From Right		Cross Traffic From Right		Right Turn From Right		All Same Directions		All Cross Traffic From Left		All Cross Traffic From Right		All Cross Traffic	
		C	SC	C	SC	C	SC	C	SC	C	SC	C	SC	C	SC	C	SC	C	SC	C	SC	C	SC	C	SC	C	SC
9:30	1982	14	4	25	15	15	10			8	3	12	4	18	3	23	5	3		54	29	20	7	44	8	64	15
																				0	0	0	0	0	0	0	0
11:30	1567	7	2	12	2	4				4		11	2	12		11	2	2		23	4	15	2	25	2	40	4
																				0	0	0	0	0	0	0	0
13:30	1623	9	4	13	1	3		1		4	1	9	1	12	1	13	1	2		25	5	14	2	27	2	41	4
																				0	0	0	0	0	0	0	0
15:30	1877	19	7	23	11	7	1			13	2	16	4	17	3	25	7	3		49	19	29	6	45	10	74	16
																				0	0	0	0	0	0	0	0
Sub Total	7049	49	17	73	29	29	11	1	0	29	6	48	11	59	7	72	15	10	0	151	57	78	17	141	22	219	39
Totals		66		102		40		1		35		59		66		87		10		208		95		163		258	
Rates/1000 vehicle		9.4		14.5		5.7		0.1		5.0		8.4		9.4		12.3		1.4		29.5		13.5		23.1		36.6	
Sever Conflicts: Between traffic from this leg and cross traffic from leg B																											
Possible Causes of Slow Vehicle Conflicts: High Speed, delays and inadeuate cycle time and violations to the fixed cycle time																											
Other Notes and Conflicts: Violations to posted speed limits, high percentage of cross traffic from leg B , pavement markings are faded, pavement surface is disturbed at approaches, buses stop suddenly at the right turn approaches, and many parked vehicles near the approaches																											

Table 14: Intersection Conflicts (Leg D)

INTERSECTION CONFLICTS																											
Location: Makhmur Intersection																				Leg Number: D							
Day: Saturday - Wednesday						Date: 10 (19 - 23) - 2022														Observer: Abdulhakim Othman Salih							
						Conflict-C								Secondary Conflict-SC													
COUNT START TIME (MILITARY)	TOTAL APPROACH VOLUME (vph)	Left Turn Same Direction		Slow Vehicle		Right Turn Same Direction		Opposing Left Turn		Left Turn From Left		Cross Traffic From Left		Left Turn From Right		Cross Traffic From Right		Right Turn From Right		All Same Directions		All Cross Traffic From Left		All Cross Traffic From Right		All Cross Traffic	
		C	SC	C	SC	C	SC	C	SC	C	SC	C	SC	C	SC	C	SC	C	SC	C	SC	C	SC	C	SC	C	SC
10:00	1684	14	5	18	7	35	24	2		4	1	14	4	11	3	13	1	24	13	67	36	20	5	48	17	68	22
																				0	0	0	0	0	0	0	0
12:00	1575	7	1	9	1	17	3			5		4		7		6	2	11	2	33	5	9	0	24	4	33	4
																				0	0	0	0	0	0	0	0
14:00	1522	9	3	7	2	14	1			7		6		9	1	7		7	1	30	6	13	0	23	2	36	2
																				0	0	0	0	0	0	0	0
16:00	1638	12	4	14	5	23	14			13	2	18	11	14	3	11	3	19	2	49	23	31	13	44	8	75	21
																				0	0	0	0	0	0	0	0
Sub Total	6419	42	13	48	15	89	42	2	0	29	3	42	15	41	7	37	6	61	18	179	70	73	18	139	31	212	49
Totals		55		63		131		2		32		57		48		43		79		249		91		170		261	
Rates/1000 vehicle		8.6		9.8		20.4		0.3		5.0		8.9		7.5		6.7		12.3		38.8		14.2		26.5		40.7	
Sever Conflicts: Between through and right turn from this leg and through from leg A and C																											
Possible Causes of Slow Vehicle Conflicts: Violations of cycle time, high speed, side obstruction due to parked buses and vehicles																											
Other Notes and Conflicts: Long delays, high percentage of trucks, and high cross traffic volume from leg C, suddenly stopping of buses and vehicles coming from leg A, near the intersection ause swerving of right turning vehicles from this leg, and problem of bus stopping at approach B which cause conjestion to the straight traffic from leg D																											

Table 15: Hazards and Inefficiencies

Class	Description	Indicator	Severity
Fixed Object	-Right turn of approach B obstructed due to too close building (i.e. Company Station) -Trees at the medians at approach B and D -Signalized control signs are the main devices for control in the intersection -Markings on all approaches -Pavement surface disturbed nearly in all approaches	Engineering Judgment Engineering Judgment Engineering Judgment Observations Engineering Judgment	High High High Low Moderate
Moving Object	-Vehicles violating traffic control signals - Vehicles making sudden conflicts (right, left, and through) from all approaches -Drivers waiting too much due to inadequate cycle time.	Right-angle and rear-end collisions High rate of conflicts between through and cross traffics High traffic volume with small portion of green time	High High High
Condition	-Sight obstructions for both flows due to trees and small structures at the median. -Frequent stopping of buses and vehicles at approaches, cause site obstruction and high traffic volumes on the major streets.	Braking conflicts close to intersection area Weaving and Braking conflicts at approaches	High High
Situation	-High percentage of trucks	Right-angle, and slow vehicle collisions	
Inefficien cies	-Excessive delays during peak period due to high traffic volumes and insufficient green time portion for each approach queue.	Long queues, and conflicts braking	Moderate

Table 16: Expectancy Analysis

Location	Location Description	Driver Response	Expectancy and Status
Approach A from Makhmur Street (North)	-A 3-lane street near intersection enlarges to one left, two straight lanes and two right turn lanes, Company station on the right side cause a dangerous sight obstruction for traffic tends to right turn from this approach.	-Desiring to go through in most cases, but some braking, and swerving conflict due to violators from other approaches and problem of sight obstruction while right turning with parking vehicles and bus stopping near at the nose of right turning and also with the right turning vehicles of approach D.	-Don't expects any violations from other approaches and problem of parking vehicles and buses. -Don't expects sight obstruction problem due to Company Station.
Approach B from Peshawa Qazi Street (East)	-A 3-lane street near intersection enlarges to two left, three straight and one right turn lanes, with high traffic volume and too much delay. Many trees on the median of left side causing problem of sight obstruction for traffic tend to turn left from this approach, especially problem of violators from approach C.	-Some times he confuses due to violators from other approaches and erratic maneuvers of right turning vehicles from approach A. Single or double conflicts causing some queues.	Expects that he has the priority to go through or left without any fixed obstructions or moving interruptions.
Approach C from Makhmur Street (South)	-A 3-lane street near intersection enlarges to two left turn and two straight lanes with additional drop lane for right turns and with high traffic volume and too much delay. -Parking vehicles and buses near the intersection.	Drivers are very conspicuous when approaching the intersection. A single and double conflict were there especially braking conflicts at morning peak hours, and long queues sometimes buildup.	-Don't expects high speed and traffic volume with frequent violations from approach B.
Approach D from Peshawa Qazi Street (West)	-A 3-lane street enlarges to three left turn, two straight and one right turn lanes with high traffic volume and high percentage of trucks and too much delays. -Small fixed structures on the median and problem of parking buses and vehicles at the approach near the nose of right turning causing a dangerous sight obstruction for left and right turning vehicles.	Some drivers became nervous, and make violations. - Erratic maneuvers and conflicts due to parking vehicles and buses at the end of right turn.	-Don't expect the high volume and queue from approach C, and parking buses and vehicles at the nose of right turn.

Table 17: Expectancy Violation Characterization

Source	Characterization	Speed	Path	Direction	Information Needs
1-Traffic Signals (inadequate cycle time)	-Generally inadequate cycle time in relation to the present traffic volume which increases delays and disobeyed by the drivers, as they are confusing.	X	X	X	-Redesign of cycle timing based on the present volume and more severe control is needed from all approaches to regulate the flow maneuvers.
2-Intersection geometry (poor decision sight distance)	-Some fixed objects on medians and near leg A cause problem of site obstruction and conflicts and confusion.	X	X	X	-Intersection condition needs more open sight distance through removing all trees and fixed objects on the medians and removing the Electricity station at the right hand of approach A
3-Traffic Flow (conflicts)	-Drivers may not expect other violators to make sudden stops or Illegal passing causing perturbation in the traffic stream.	X	X	X	-Same as 1 and 2
4-Environment (Weather)	-Wet conditions enlarge the above situation.	X			-Same as 1 and 2

Table 18: Description of Detection and Recognition Problems

No.	Hazard Inefficiency	Detection or Recognition Problems	Compensation Information
1.	**Unexpected Stops**	Detection: Intersection alignment and queue formation hinder detection of vehicles unexpectedly, particularly at right turns.	-Unexpected stops and conflicts are a result of drivers not following the correct path through all approaches to get where they are going, due to stopping buses and vehicles near the approaches-at right turns- and sight obstruction. More efficient directional control is needed for drivers to follow their directions smoothly without conflicts and preventing bus and vehicle stopping near the approaches.
2.	**Unseperated Lanes**	Detection and Recognition: Built-up of queues especially with trucks, making congestion and erratic maneuvers, which hinder recognition by the uncommon appearance of barricaded in traffic lanes.	-Separated lanes for each direction are required, taking into consideration the maximum amount of trucks and buses using the intersection according to peak traffic volumes.
3.	**Illegal movement**	Detection and Recognition: Unsatisfaction with the cycle time, especially the insufficient green portion, causing drivers to perform illegal movement and conflicts with traffic movement from other approaches.	-Redesign of cycle time according to the present peak hour volumes.
4.	**Oversaturation**	Detection: Low capacity and unsatisfactory present cycle time causing congestion and conflicts especially for vehicles going left. Recognition: Long delays or sometimes queues.	-Same as 3.
5.	**Fixed Objects**	Some of the fixed objects can't be detected due to obstructions, and other roadway environment i.e. trees.	-Fixed objects here are not important for traffic arrangement and flow, need to be removed.

Table 19: Delay Analysis based on Proposed Cycle Time

Delay Analysis											
Intersection	Proposed Cycle Time, C_o							HCM	Dav.	LOS
Name	App.	q	S	C_o	g	λ	X	C	Delay	Sec/hr	
Makhmur	N_{st}	506	5225	120	14	0.12	0.83	610	45.97	43	E*
	N_l	173	1672	120	14	0.11	0.91	191	67.90		
	S_{st}	1052	7058	120	40	0.33	0.45	2353	23.91		
	S_l	510	1694	120	40	0.33	0.91	563	42.15		
	E_{st}	554	5403	120	20	0.17	0.62	901	36.20		
	E_l	543	3458	120	20	0.17	0.94	576	55.06		
	W_{st}	738	3300	120	30	0.25	0.91	815	43.14		
	W_l	482	4950	120	30	0.25	0.39	1238	28.52		

* According to HCM, for Dav.= 40 - 60 sec/hr.

LEGENED
q =Traffic demand - pcu/h.
C_o = Cycle time - sec.
X = Degree of saturation = q/C
g = Effective green time - sec.
λ= Green ratio = g/C_o
S= Saturation flow rate - pcu/h.
st= Straight through lanes
C = Capacity of lane group (pcu/h) = S*g/C_o
HCM= Highway Capacity manual delay formula

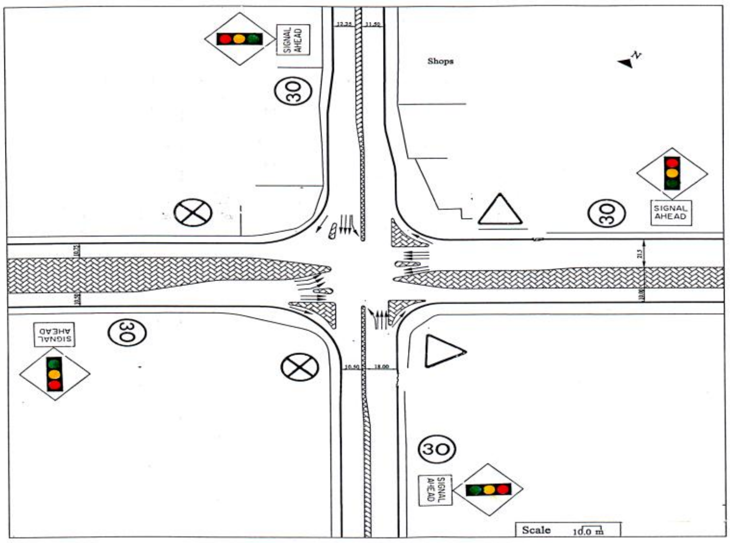

Figure 6: Final Safety Improvement Design

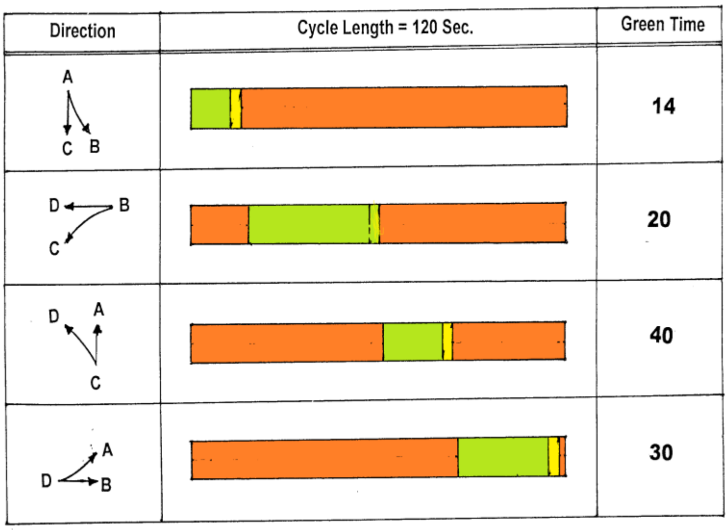

Figure 7: Phase Length Time Table

4.CONCLUSIONS

The main conclusions that may be obtained from the current research are as follows:

1. Positive guidance procedure , initiated by FHWA , which was completely applied in the site investigation analysis phase for the hazardous case (Makmur Intersection), is approved to be very active in the diagnosis operation implemented to put the perfect solution for the site investigated ;
2. This study reveals that the identification of accident-causing factors is a very complex process and requires proactive decisions to reduce accidents on the intersections systematically so that road accidents can effectively be drastically reduced in the future;
3. Through the analysis of the collected accident data related to this worst intersection, by the aid of (SPSS) computer package, noticed that the highest number of accidents happened at morning and afternoon peak hours(i.e.7:00-8:00a.m.and12:00-14:00p.m.),also on May and December (9 & 8 of 54) accidents respectively, and at Saturday and Wednesday were the largest (13 and 14 accidents of 54 respectively),nearly all accidents (52 of 54) accidents are dominant collision type, which resulted in (1) deaths, (43) injuries and (118) vehicles damaged during the study period, the Property Damage Only (PDO) accidents are the dominant type(36 of 54) accidents, that proves accidents involving property damage are significantly more common at signalized intersections;
4. From the collision diagram, the right angle collisions are the dominant type (22 of 54 accidents) and nearly all the accidents occurred

under dry weather conditions due to vehicles at high speed and without care to traffic signals.

5. Conflicts are able to describe accidents behavior at a certain intersection by observing the different types of these conflicts in the site during the deep analysis of that site and high traffic volume and inadequate cycle time offer the explanation of the relatively high frequency of conflict rates, since the conflicts occurs in the same area.
6. Condition diagram plotted for the location-which need more investigation-sometimes can be used to decide some safety improvement and alternative solutions in the office without conducting a site investigation process;
7. Manual observations of driver performance, driving through, and video logging processes can be considered as an active tools for diagnosing hazards at a specified intersection to decide a convenient safety correction for it; and
8. Delay analysis, with making use of present cycle time (79 sec) and traffic volume in each approach during the a.m. peak hour, results the average delay of (83 sec). This result indicates the high deficiency and low level of service (LOS) during peak hour demand. According to (HCM) the level of service was (F), as the average stopped delay for vehicles was more than (60 sec.),also delays on the approaches were higher than usual due to improper signal timing and inadequate green portion for high volume of traffic on the streets . Accordingly the proposed cycle time(120 sec.) minimizes the total average delay to (43 sec.) and (LOS) is modified to level (E) by redesigning the cycle time

ACKNOWLEDGEMENT

The author express his appreciations to the different road agencies of Erbil city/Iraq especially Erbil Traffic Police Directorate for providing the necessary data and relevant information for this study. Also, deepest gratitudes from the author to all the persons who participated in one way or another in this work and gratefully acknowledge any help and information received to complete this study.

REFERENCES

AASHTO, 2010. American Association of State Highway and Transportation Officials (AASHTO). “Highway Safety Manual”, 1st Edition, Washington, D.C., 2010.

Anand Rangarajan & Sanjay Ranka;”Using Video Analytics to Improve Traffic Intersection Safetyand Performance”, *Vehicles* 2022, *4*, 1288–1313. https://doi.org/10.3390/vehicles4040068 https://www.mdpi.com/journal/vehicles

Athiappan, K. et.al. 2022. K. Athiappan, et.al,; “Identifying Influencing Factors of Road Accidents in Emerging Road Accident Blackspots” | Article ID 9474323 | Volume 2022.

Azadeh, A., 2016; A. Azadeh M. Zarrin, and M. Hamid, “A novel framework for improvement of road accidents considering decision-making styles of drivers in a large metropolitan area,” *Accident Analysis and Prevention*, vol. 87, pp. 17 – 33, 2016.

Bin Islam, M. &Kanitpong, K., 2008; “Identification of factors in road accidents through in-depth accident analysis,” *IATSS Research*, vol. 32, no. 2, pp. 58–67, 2008.

Debrabant B.et.al.,2018;B. Debrabant, U. Halekoh, W. H. Bonat, D. L. Hansen, J. Hjelmborg,and J. Lauritsen, “Identifying traffic accident black spots with poissontweedie models,” *Accident Analysis and Prevention*, vol. 111, pp. 147 – 154, 2018.

FARS,2022; Fatality Analysis Reporting System (FARS). Available online: https://www.nhtsa.gov/research-data/fatality-analysis-reportingsystem-fars (accessed on 15 August 2022)

FHWA, 2017. Federal Highway Administration, “Road Safety Fundamentals: Concepts, Strategies, and Practices that Reduce Fatalities and Injuries on the Road” FHWA Office of Safety, Updated June 2017.

FHWA, 2017. FHWA Safety Program” Highway Safety Improvement Program (HSIP) Evaluation Guide” U.S.Department of Transportation, Federal Highway Administration. May 2017.

FHWA, 2014, Federal Highway Administration, “Road Safety Audit Guidelines”, Publication FHWA-SA-06-06, February 2014.

FHWA, 2016, Federal Highway Administration; “Reliability of safety Management Methods: Diagnosis”, U.S. Department of Transportation, September 2016.

FHWA, 2017, Federal Highway Administration; “Road Safety Fundamentals”, U.S.Department of Transportation, 2017

FHWA, 2020; “Manual on Uniform Traffic Control Devices”, U.S. Department of Transportation, Washington, 11th Edition 2020.

Gerson J.A&Harold,L.,2009.Gerson J.Alexander&Harold Lunenfeld, “A users' guide to positive guidance in highway control", Federal Highway Administration, US Department of Transportation, Washington, D.C.2009.

Hagenzieker, M.P., 2014; M. P. Hagenzieker, J. J. Commandeur, and F. D. Bijleveld, "Thehistory of road safety research: A quantitative approach," *Transportationresearch part F: traffic psychology and behaviour*, vol. 25, pp. 150–162, 2014.

HCM, 2022;"Highway Capacity Manual", Transportation Research Board (TRB) publications, Washington D.C., 7th Edition, 2022.

Herbel, S. et al.2010.Herbel, S., Laing, L.and.McGovern.C,"Highway Safety Improvement Program Manual", Cambridge Systematics, Inc., FHWA-SA-09-029, Cambridge, MA, 2010.

HSIP, 2016; Highway Safety Improvement Program" Implementation Guidance*"23 CFR Part 924, 2016*

HSIP,2018, "Metro District Program Criteria" Highway Safety Improvement Program For State Fiscal Years 2022 and 2023 Minnesota Department of Transportation,Metro District Traffic Engineering June 2018

Hss,2020. Incorporating the comments of HSS Committee "Guidelines for Identifying and Treating Blackspots" (for the considerations of Council) IRC SP: XXX 2020.

https://www.google.com/maps/@36.189949,44.011721 1,14z/data=!5m1!1e1?hl=en

Hussain, M. et.al.2021, Muhammad Hussain, Jing SHI, Yousaf Ali;" Accident Analysis and Identification of Black Spots on the Motorways in Pakistan - a Reliability Analysis Approach" Mehran University Research Journal of Engineering and Technology,Vol. 40, No. 4, 692 - 702, October 2021 Roy,D..et.al. 2019; Debaditya Roy, Tetsuhiro Ishizaka, C.

Kononov, J, Janson, B.N., 2002; Jake Kononov and Bruce N. Janson "Diagnostic Methodology for the Detection of Safety Problems at Intersections"Transportation Research Record 1784 ■ 51Paper No. 02-2148, 2002

Krishna Mohan, and Atsushi Fukuda "Detection of Collision-Prone Vehicle Behavior at Intersections using Siamese Interaction LSTM", arXiv: 1912.04801v1 [cs.CV] 10 Dec 2019

Mishra,A.,et.al.,2022, Ahan Mishra , Ke Chen , Subhadipto Poddar , Emmanuel Posadas , Anand Rangarajan and Sanjay Ranka;"Using Video Analytics to Improve Traffic Intersection Safetyand Performance",*Vehicles* 2022, *4*, 1288–1313. https://doi.org/10.3390/vehicles4040068 https://www.mdpi.com/journal/vehicles

M.Ghadi & A.Torok,,2017; "Comparison of different black spot identification methods,"*Transportation Research Procedia*, vol. 27, pp. 1105– 1112, 2017, 20th EURO Working Group on Transportation Meeting,EWGT 2017, 4-6 September 2017, Budapest, Hungary

M.Ghadi&A.Torok, 2019; "A comparative analysis of black spot identification methods and road accident segmentation methods," *AccidentAnalysis and Prevention*, vol. 128, pp. 1 – 7, 2019.

Mohsen, H. S.& Moghaddam G. V. N.2020.Mohsen, H. S.and Moghaddam Gilani V. N., "Analysis of Factors Affecting Urban Road Accidents in Rasht Metropolis," 2020.

N.H.T.S.Administration *et al.*, 2010;"Crash factors in intersection-related crashes: An on-scene perspective," *Nat. Center Stat. Anal., NationalHighway Traffic Safety Administration, Washington, DC, USA, Tech.Rep. DOT HS*, vol. 811366, 2010.

Prieto, F., 2014; F. Prieto, E. Gmez-Dniz, and J. M. Sarabia, "Modelling road accidentblackspots data with the discrete generalized pareto distribution," Accident Analysis and Prevention, vol. 71, 2014.

RITSP, 2001;" Black Spot Manual" General Directorate of Highways, Road Improvement and Traffic Safety Project, SweRoad, ANKARA, December 2001.

Sandhyavitri A., 2016; A. Sandhyavitri, Zamri, S. Wiyono, and Subiantoro, "Three strategiesreducing accident rates at black spots and black sites road in riauprovince, indonesia," *Transportation Research Procedia*, vol. 25, pp.2153 – 2166, world Conference on Transport Research - WCTR2016 Shanghai. 10-15 July 2016.

Sayed, T.1997, Tarek Sayed; "The Highway Safety Expert System: Diagnosing Accident Prone Locations",Civil Engineering Systems , Volume 14, 1997 - Issue 4

Sayed,T.et.al,1997 ,T. Sayed, F. Navin, and W. Abdelwahab;" A countermeasure-Based Approach for Identifying and Treating Accident Prone Locations" Can. J. Civ. Eng. Vol. 24, (1997)

Shafabakhsh,G,Saj,Y.2022, Gholamali Shafabakhsh1,&Yousef Saj;" Identification Methods of Accident Hotspots and Providing a Model for Evaluating the Number and Severity of Accidents on Roadways",International Journal of Transportation Engineering,Vol. 10/ No.1/ (37) Summer 2022 IJTE, Vol. 10, No. 1, Summer 2022, pp. 865-875

Shivani, S & Sebastian, S., 2019; "IoT based car accident detection and notification algorithm for general road accidents", International Journal of Electrical and Computer

Engineering (IJECE),”*International Journal of Electrical and Computer Engineering*, vol.9, no.5, 2019.

Singh S. & Patel S. S., 2020; Shailendra Singh, and Shiva Singh Patel;” BLACK SPOT ONHIGHWAY AND REMEDIALMEASURES: A REVIEW” International Journal of Creative Research Thoughts (IJCRT) Volume 8, Issue 3 March 2020

Singh S., 2017; “*Road Traffic Accidents in India: Issuesand Challenges.* Transportation”, *Research Procedia*, Vol. 25, pp. 4712-4723, 2017.

SPSS, 2022. “Statistical Package for the Social sciences", version 29, 2022.

Tsapakis, I et al., 2017.Ioannis Tsapakis et al: “Innovative tools and techniques in identifying highway safety improvement projects: technical report” Texas Department of Transportation, 2017.

Wan, Y., et.al.2021, Yan Wan, Wenqiang He and Jibiao Zhou;“Urban Road Accident Black Spot Identification and Classification Approach: A Novel Grey Verhuls–Empirical Bayesian Combination Method”,*Sustainability* 2021, *13*, 11198. https://doi.org/10.3390/su132011198

WHO, 2018. Who “*Global Status Report on Road”*, World Health Organization, Beijing, 2018.