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On-Site Investigation and Diagnosis of Hazardous Street Section in Erbil Street Network

Abdulhakim Othman Salih kozapanky[1]

1Department of Civil Eng., College of Engineering, Salahaddin University - Erbil, Erbil, Kurdistan Region, Iraq

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*Corresponding author

Abdulhakim Othman Salih kozapanky

Abdulhakim.Salih@su.edu.krd

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ABSTRACT

Accidents place a significant burden on the national economy due to their potential to cause disability, death, health issues, property damage, social distress, and environmental harm. The current study seeks to investigate an accident prone location in Erbil Street Network "in Kurdistan region- Iraq" and implement the procedures outlined in the Highway Safety Improvement Program (HSIP). The process involves characterizing the accidents, diagnosing the issues, and assessing field conditions to identify the contributing factors. Based on this, countermeasures are suggested to significantly improve safety. Factor analysis was employed to determine and rank the most influential factors contributing to the accidents. By addressing these significant factors with targeted measures, future accidents can be reduced.Data analysis was conducted focusing on micro-level factors such as traffic characteristics, road user behavior, collision types, road and geometric features, street furniture, and environmental conditions.The study involved characterizing accidents, diagnosing field conditions, identifying contributory factors, and recommending countermeasures to substantially enhance safety. Through the analysis of the collected accident data, it is shown that run over (pedestrian accidents) is the dominant type and happened at morning and afternoon peak hours. It contribute to vehicles speed which generally exceeded the average speed for the link.The output of the diagnosis phase is a set of applicable countermeasures for the accident prone location and the degree of confidence in each countermeasure.This research will assist transportation designers in understanding accident causes and implementing appropriate measures during road construction planning and for existing conditions. It provides a framework for reducing accidents both in the short term and over the long term.

1. Introduction

Road networks are intricate, evolving, and uncertain systems affected by human, technological, and environmental factors, leading to road accidents (BNCR, 2020). Research has shown a strong correlation between road accidents and the road's geometric features, such as sight distance, curvature radius, and slope (Mohan et al., 2020; Ruikar, 2013). Accidents tend to rise with longer tangent lengths, higher peak hour volumes, and greater longitudinal pitch, but decrease with a larger curvature radius (Himanshi, 2020). Additionally, the relationship between speed variations and longitudinal gradient impacts efficiency, leading to traffic congestion, reduced safety, and increased accident risk (SaveLIFE Foundation, 2017). This affects both driving sight distance and driver behavior, including overtaking. The effects of longitudinal surface friction and pavement are more pronounced on steep slopes, raising the likelihood of accident (Gregoriades & Mouskos, 2013).

Recent research has highlighted that road crashes resulting in severe injuries are a major public health concern. Therefore, stricter countermeasures should be implemented to decrease the frequency of these serious accidents and achieve better long-term outcomes (Athiappan et al., 2022; Islam Bin & Kanitpong, 2008)

This study demonstrates that pinpointing the factors that cause accidents is a highly complex task. It requires proactive measures to systematically reduce road accidents, aiming for a significant decrease in future incidents.

Therefore, it is essential to determine the causes of accidents and implement suitable corrective measures both during the road construction planning phase and under current conditions (Rolison et al., 2018; WHO, 2018).

The Highway Safety Improvement Program (HSIP) seeks to decrease the number and severity of fatalities and serious injuries on public roads by applying safety improvement plans (Gross, 2017; Tsapakis et al., 2017). It includes three main components: planning, implementation, and evaluation. This guide concentrates on the evaluation component, which offers essential feedback to refine processes and guide future decisions (Gross, 2017).

The Roadway Safety Management Process outlined in the Highway Safety Manual (HSM) illustrated in Fig. 2 below (American Association of State and Highway Transportation Officials (AASHTO), 2010; Tsapakis et al., 2017).

In the overall safety management framework, diagnosis and countermeasure selection, which follow network screening, are the second and third steps, respectively (Tsapakis et al., 2017). The goal of diagnosis is to uncover crash patterns, contributing factors, and deficiencies at problem areas. This process typically includes reviewing crash history, traffic operations, and site conditions. Proper diagnosis is crucial before developing countermeasures, much like a doctor diagnoses an illness based on symptoms before prescribing treatment. Without this careful analysis, resources may be wasted on countermeasures that don't address the root problems (Carter et al., 2017).

The diagnosis process gives a fundamental idea about the crash patterns, collision causes, and the current roadway conditions at hot locations identified through network screening. This insight forms the basis for choosing suitable countermeasures for each site .

The HSM outlines three key activities involved in the diagnosis process: a) Review safetydata, b)Evaluate supporting documentation, and c) Examine field conditions (Herbel et al., 2010a; Tsapakis et al., 2017).

The result of diagnosis phase along with level of confidence in the effectiveness of each countermeasure is a list of suitable countermeasures for each accident prone location.

Positive Guidance is a method designed to improve safety and operational efficiency at hazardous locations. It combines highway engineering with human factors technologies in order to develop a customized information system based on the unique features of location and characteristics of drivers. The Users' Guide to Positive Guidance helps in analyzing the site and develop most effective solutions. This guide details a process with six essential functions: gathering information in the problem areas, identifying issues, defining factors influencing driver performance, determining the requirements for the information system, creating information in positive guidance, and conducting evaluations (Gerson & Harold, 2009; Herbel et al., 2010b).

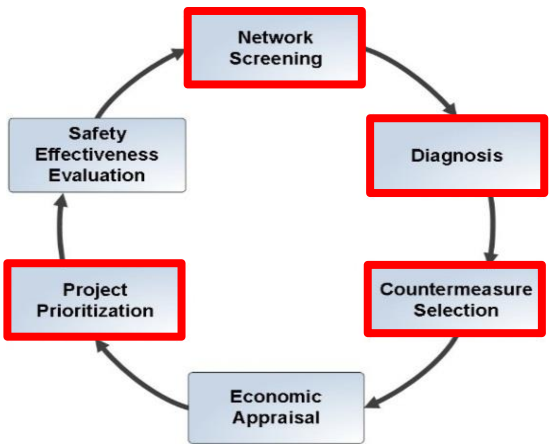


Figure 2: HSM Roadway Safety Management Process (American Association of State and Highway Transportation Officials (AASHTO), 2010)

2. METHODOLOGY (POSITIVE GUIDANCE PROCEDURES)

The study involves a thorough diagnosis and site investigations of the most hazardous location within the Erbil Street Network. During the diagnostic phase, the problematic site was identified, and the Federal Highway Administration (FHWA) outlined the Positive Guidance Procedures were fully applied to this location (Carter et al., 2017). Five of these Positive Guidance procedures were implemented as part of the preliminary (Before Study) phase of the investigation, with suggested safety enhancements derived from these procedures. The sixth procedure, representing the (After Study) phase, is to be carried out after the recommended safety improvements have been made at this location.

The hazardous location chosen as a worse – black-spot was a street section of Kurdistan Ring Street (60 meter Street), located between Badawa T- intersection and Chinarok Interchange of 1.15 Km in length of 6-lanes- 2 ways category, selected as the worst section identified as hazardous in the sample street network considered in this study. Fig.1 shows the street link location map.

The location was thoroughly examined to determine the procedures necessary for diagnosing other hazardous areas or spots. This analysis aims to improve safety measures and reduce future accidents in these identified sections.

Figure 1: Street Link Location Map in Erbil Street Network (● The study area) (https://www.google.com/maps/@36.188074,44.0080013,14z?hl=en.)

2.1. Collection of Data (Function A)

To conduct the present study, some existing information and data are needed like: accident records, traffic studies, video filming, and site configurations. These maps had been prepared by the study by field survey work carried out, besides found very suitable in constructing diagrams presented in the subsequent functions.

Through the accident details, the worst segment was found as this section in which accidents try to accumulate during three years period of study among (2020 - 2022). During the study period 67 accidents occurred, which about 5.3% is of total accidents on the street sections in the study area. 53 of these accidents in this segment were pedestrian accidents.

The site condition diagram in Fig.3 shows this hazardous section. In this figure all the control devices are fixed up on their right locations during the site investigation process.

Accident data were analyzed to understand accident characteristics and identify potential trends or specific issues. Statistical Package for the Social Sciences (SPSS) version 29 (SPSS, 2022), different cross-relations were examined. For instance, **Table 1** presents an analysis of accidents by hour, highlighting peak times during the day. The high frequency of accidents occurred at 9:00 and 10:00 a.m. (14 out of 67 accidents) and at 14:00, 15:00, and 18:00 p.m. (21 out of 67 accidents), with a total of 35 out of 67 accidents occurring during the top five peak hours.

Table 2 presents an analysis of accidents by month, revealing that June and July had the highest number of accidents (18 out of 67) , because there is huge movement to northern parts of Erbil through these two months. **Table 3** provides a breakdown of accident analysis by day of the week, showing that Saturday and Sunday had most accidents (13 and 14 out of 67, respectively), with Wednesday also experiencing a significant number (13 out of 67),as these days are the beginning and end of week.

Table 4 illustrates the annual accident data, indicating a higher number of accidents in the last two years compared to the first year, suggesting an increasing trend in accidents for this segment. **Table 5** analyzes the types of accidents in the study segment, highlighting that run over (pedestrian) accidents are the most common (53 out of 67), with these accidents resulting in 4 fatalities and 52 injuries during the study period, because there is some children schools, hospitals and different markets on this street section with too much pedestrian movement.

Table 6 examines accident severity, showing that injury accidents are the most prevalent (55 out of 67), as this result is familiar to urban streets. Lastly, **Table 7** analyzes accidents by light conditions, indicating that daytime accidents are more frequent (54 out of 67) compared to accidents occurring in darkness (13 out of 67), due to high traffic volume in day time compared to nighttime.

Fig.4 shows the types of collisions on the accident strip diagram with their reported approximate locations.

Traffic and geometric data were collected and as mentioned before, the segment length measured is about 1.15 km with the category of 6-lane –2 ways, divided by median.

During the process of moving vehicle technique, the traffic data was collected, and the peak hour volume was about 2446 veh(pcu)/hr (for both directions). The average space mean speed was 39km/hr, and the average density was 63 veh/km. Combining this information with the accident data, an accident rate per km was (59.82) and accidents per million vehicle–kilometer was (22.2) which was computed previously for the study section.

The data analyzed shows that there are elements necessary for further investigation:

- Erratic maneuvers in the form of lane changes in both directions on the street section (i.e. inner and outer portion);
- Speeds through the section;
- Absence traffic control devices;
- Sight distance was checked;
- Pavement conditions were observed;
- A.m. and p.m. peak period operations were observed;
- Sources of driver confusion (expectancy, detection, and recognition violations).

Driving through and operation observation were taking place after completing the historical data review. This sequence permitted the observers to be sensitive to the problem indicators listed above. The data on driving through and operation observations was collected in different times on Sunday. The drive through were conducted at the speed of 40 km/h. The following notations were made:

- Vehicles generally exceeded the average speed for the link, which was measured by moving vehicle technique as 39 km/h;
- Traffic control device locations were not updated;
- There were a large number of curb parking vehicles and bus stops at the location;
- The configuration of the merging area within the location is not clear and safe;
- Sight distance is limited, because of bus stops and parking vehicles especially for those drivers running in the location (1), which composes most of the traffic there;
- The asphalt pavement is in good condition, but could be hazardous under wet conditions while there is rain or problem with drainage and accumulating water on the street; and

- The driver expectancy violations ,detection and recognition problems, will be analyzed in greater detail in subsequent function:

After completing the drive through, the observers watched the traffic movements through the section (link). Observations were made at location (1) of the link (see **Fig.4)**, for six hours during a.m. and p.m. periods of week start days (Saturdays and Sundays). The following notations were made:

- Lane change maneuvers were observed in both directions;
- No sign before the location showing the condition downstream;
- Pavement is in good condition, but it may be unsafe in wet condition;
- The visibility at the location is poor due to lack of sight distance by too many parking vehicles;
- Improper merging of vehicles near the location due to the high speed of vehicles there and unavailability of speed change lanes at the U- turns;
- Due to the lack of special places for pedestrian crossing, pedestrians were crossing randomly, which create confusion with the forward fast moving vehicles;
- Several vehicles are braking in the traffic stream, at the conflict areas on the street location;
- A peak period of flow headways is so small that conflicts in the form of braking light, horns, over takings are taking place;
- Congestion and loss of capacity are the most popular situations at peak periods, especially on Summer Saturdays and Sundays, and
- High speed on the link especially on location under consideration.

The following tasks conducted to get more detailed information:

- A drive through video film was made for the site and volume counted by manual count from a video;
- Volume counts by lane were made at the inner and outer portion of the segment (see **Fig.3)** for 6 hours throughout a peak period of a weekday (on Sunday). The results are shown in **Tables 8and10**;
- Erratic maneuvers (lane changes) were recorded at inner and outer portion of the segment (see **Fig.3**) and shown in **Tables 9 and 11**;
- Spot speed data were taken in addition to the speed taken before by moving vehicle technique, using a stop watch and lane markings in inner and outer portions of the segment during the two peak periods, the results are shown in **Tables 12 and 13 and illustrated in Figs.5 and 6**;
- Headway time was measured at both portions and summarized in **Table 14**; and

The subsequent functions are based on the data from the above tasks:

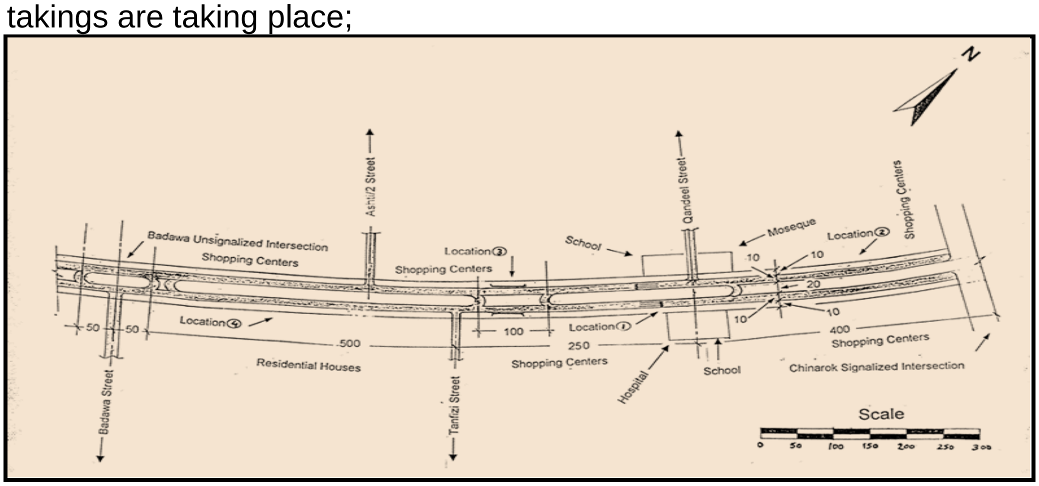


Figure 3: Site Condition Diagram

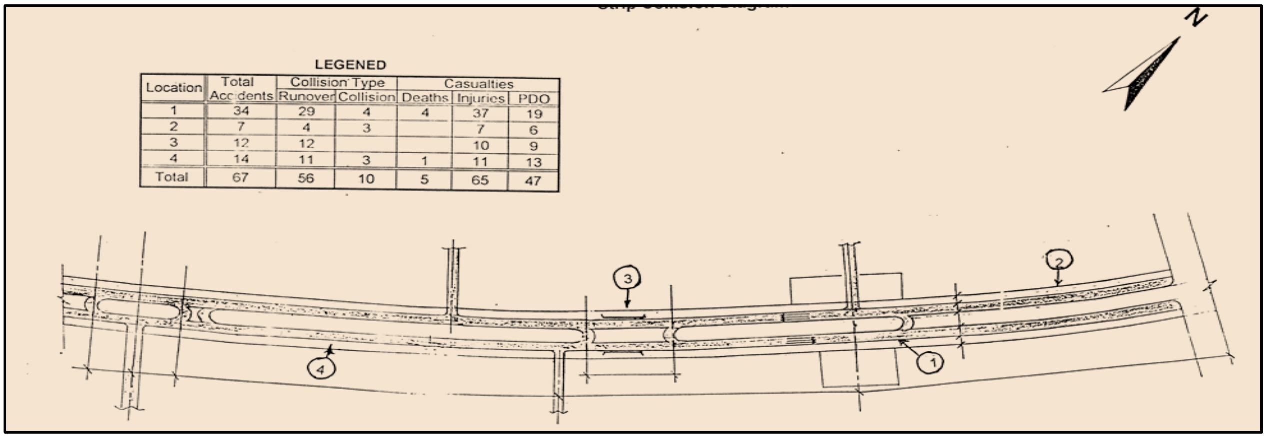


Figure 4: Strip Collision Diagram

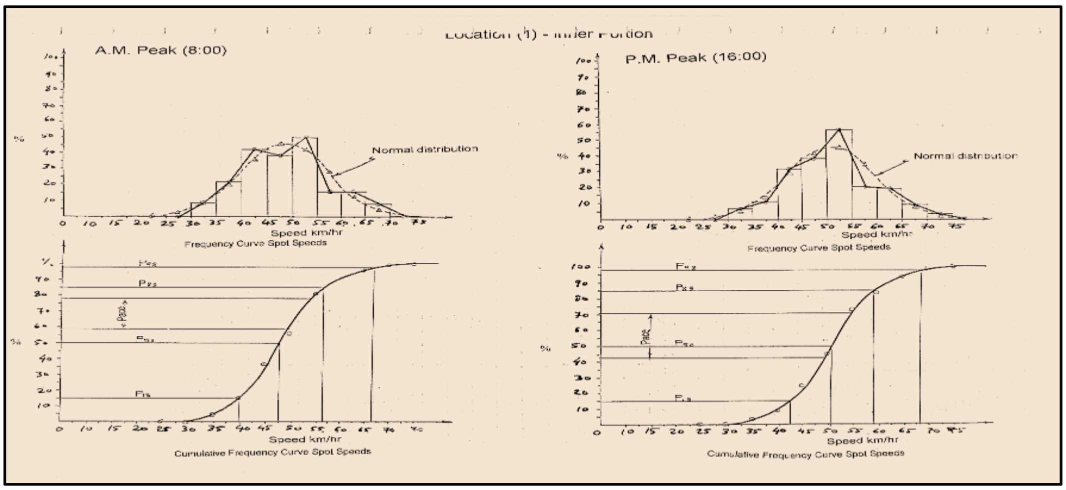


Figure 5: Cumulative Frequency Curve Spot Speed [Location 1-Inner Portion]

Table 1: Accident Distribution by Hour of Day during the Study Period (2020-2022)

Hour	Day of Month																										Total	
	1	3	4	5	6	7	9	10	11	12	13	14	15	16	17	18	21	22	23	24	25	26	27	29	30	31	No.	%
700		1																				1					2	3
800			1									2			2				1				1				7	10
900				1						2		2		1				1									7	10
1000			1					1		1			1														4	6
1100														2													2	3
1200			1		1	1				1																1	5	7
1300			1		1				2		1											1					6	9
1400							1						1	1		1	1	1						1			7	10
1500					1			2								1	1			1		1					7	10
1600	1										1			1			1										4	6
1700							1											1									2	3
1800				1				1					1								1	2				1	7	10
1900						1		1							1							1					4	6
2000					1																						1	1
2100										1																	1	1
2400										1																	1	1
Total	1	1	4	2	4	2	2	5	2	6	2	4	3	5	3	2	3	3	1	1	1	6	1	1	0	2	67	100

Table 2: Accident Analysis for Severity by Month of Study Period

Month	Total Accidents		Deaths		Injuries		Property Damage Only(PDO)	
	No.	%	No.	%	No.	%	No.	%
1	1	1			1	2	0	0
2	3	4			3	5	0	0
3	5	7			5	8	2	4
4	7	10			8	12	6	13
5	7	10	2	40	5	8	5	11
6	9	13	1	20	7	11	11	23
7	9	13			8	12	7	15
8	3	4			3	5	2	4
9	7	10			9	14	2	4
10	4	6			4	6	2	4
11	6	9	1	20	7	11	9	19
12	6	9	1	20	5	8	1	2
Total	**67**	**100**	**5**	**100**	**65**	**100**	**47**	**100**

Table 3: Accident Analysis by Day of Week

Week	Total Accidents		Deaths		Injuries		PDO		Light Condition				Severity			Type			Year		
	No.	%	No.	%	No.	%	No.	%	Day	%	Night	%	Fatal	Injury	PDO	Run.	Coll.	Over.	2020	2021	2022
Saturday	13	19	1	20	12	18	10	21	8	15	5	38	1	11	1	10	3		5	3	5
Sunday	14	21	2	40	9	14	8	17	13	24	1	8	2	9	3	11	2	1	2	7	5
Monday	8	12		0	10	15	7	15	7	13	1	8		8		6	2		3	3	2
Tuesday	7	10		0	9	14	4	9	4	7	3	23		7		7			1	2	4
Wednesday	13	19	1	20	15	23	5	11	12	22	1	8	1	11	1	11	2		3	4	6
Thursday	6	9	1	20	3	5	6	13	5	9	1	8	1	3	2	4	2		3	3	
Friday	6	9		0	7	11	7	15	5	9	1	8		6		4	2		2	2	2
Total	**67**	**100**	**5**	**100**	**65**	**100**	**47**	**100**	**54**	**100**	**13**	**100**	**5**	**55**	**7**	**53**	**13**	**1**	**19**	**24**	**24**

Table 4: Accident Analysis by Year (2020-2022)

year	Total Accidents		Deaths		Injuries		PDO		Light Condition				Severity			Type		
	No.	%	No.	%	No.	%	No.	%	Day	%	Night	%	Fat.	Inj.	PDO	Run.	Coll.	over.
2020	19	28		0	19	29	15	32	17	31	2	15		17	2	13	6	
2021	24	36	4	80	24	37	13	28	22	41	2	15	4	17	3	20	4	
2022	24	36	1	20	22	34	19	40	15	28	9	69	1	21	2	20	3	1
Total	**67**	**100**	**5**	**100**	**65**	**100**	**47**	**100**	**54**	**100**	**13**	**100**	**5**	**55**	**7**	**53**	**13**	**1**

Table 5: Accident Analysis by Type of Accident

Type	Total Accidents		Deaths		Injuries		PDO		Light Condition				Severity		
	No.	%	No.	%	No.	%	No.	%	Day	%	Night	%	Fat.	Inj	PDO
Runover	53	79	4	80	52	80	17	36	40	74	13	100	4	49	
Collision	13	19	1	20	13	20	28	60	13	24			1	6	6
Overturn	1	1			0	0	2	4	1	2					1
Total	**67**	**100**	**5**	**100**	**65**	**100**	**47**	**100**	**54**	**100**	**13**	**100**	**5**	**55**	**7**

Table 6: Accident Analysis by Severity of Accident

Severity	Total		Deaths		Injuries		PDO		Light			
	No.	%	No.	%	No.	%	No.	%	Day	%	Night	%
Fatal	5	7	5	100	4	6	17	36	3	6	2	15
Injury	55	82			61	94	28	60	44	81	11	85
PDO	7	10					2	4	7	13		0
Total	**67**	**100**	**5**	**100**	**65**	**100**	**47**	**100**	**54**	**100**	**13**	**100**

Table 7: Accident Analysis by light Condition

Light	Total		Deaths		Injuries		PDO	
	No.	%	No.	%	No.	%	No.	%
Day	54	81	3	60	54	83	41	87
Night	13	19	2	40	11	17	6	13
Total	**67**	**100**	**5**	**100**	**65**	**100**	**47**	**100**

Table 8: Lane Volume by Time of Day

[Location (1) -Inner Portion Lane Volumes]

Time Period	Lane 1	Lane 2	Lane 3	Total
7:30-8:00	430	381	300	1110
8:10-8:40	470	429	333	1232
8:50-9:20	395	364	281	1040
9:30-10:00	364	330	257	950
12:00-12:30	327	301	232	860
12:40-13:10	323	290	227	840
13:20-13:50	372	348	260	980
14:00-14:30	386	355	274	1015
14:40-15:10	437	403	311	1150
16:00-16:30	467	433	330	1230
16:40-17:10	460	424	327	1210
18:00-18:30	452	417	321	1190
Total volume	**4883**	**4475**	**3453**	**12807**
% of Total	**38**	**35**	**27**	**100**

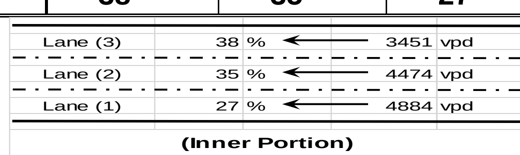


Table 9: Percent Lane Changes* [Location (1) -Inner Portion]

Time Period	1~2	2~3	3~2	2~1	Total Conflicts
7:30-8:00	2.5	5.1	8.5	6.9	23
8:10-8:40	3.0	5.9	10.0	8.1	27
8:50-9:20	2.4	4.8	8.1	6.6	22
9:30-10:00	2.0	4.0	6.7	5.4	18
12:00-12:30	1.3	2.6	4.4	3.6	12
12:40-13:10	1.2	2.4	4.1	3.3	11
13:20-13:50	1.5	3.1	5.2	4.2	14
14:00-14:30	1.4	2.9	4.8	3.9	13
14:40-15:10	2.0	4.0	6.7	5.4	18
16:00-16:30	2.8	5.5	9.3	7.5	25
16:40-17:10	3.2	6.4	10.7	8.7	29
18:00-18:30	3.4	6.8	11.5	9.3	31
Average (%)**	**2.2**	**4.5**	**7.5**	**6.1**	**20.3**

*Based on lane volumes from **Table8.**

**Percent of total lane changes observed during six hours of sampling

Table 10: Lane Volume by Time of Day

[Location (1) -Outer Portion Lane Volumes]

Time Period	Lane 1	Lane 2	Lane 3	Total
7:30-8:00	424	210	285	1019
8:10-8:40	451	341	308	1100
8:50-9:20	402	300	278	980
9:30-10:00	361	273	246	880
12:00-12:30	326	249	220	795
12:40-13:10	337	250	228	815
13:20-13:50	390	295	266	950
14:00-14:30	426	310	286	1021
14:40-15:10	491	400	339	1210
16:00-16:30	504	381	344	1230
16:40-17:10	513	388	350	1250
18:00-18:30	487	371	330	1188
Total Volume	**5112**	**3768**	**3480**	**12438**
% of Total	**41**	**31**	**28**	**100**

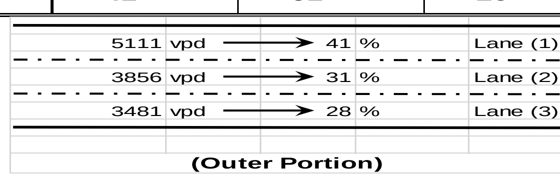


Table 11: Percent Lane Changes*[Location (1) -Outer Portion]

Time Period	1~2	2~3	3~2	2~1	Total Conflicts
7:30-8:00	2.8	3.9	11.2	10.1	28
8:10-8:40	3.0	4.2	12.0	10.8	30
8:50-9:20	2.3	3.2	9.2	8.3	23
9:30-10:00	1.9	2.7	7.6	6.8	19
12:00-12:30	1.4	2.0	5.6	5.0	14
12:40-13:10	0.9	1.3	3.6	3.2	9
13:20-13:50	1.5	2.1	6.0	5.4	15
14:00-14:30	1.3	1.8	5.2	4.7	13
14:40-15:10	2.0	2.8	8.0	7.2	20
16:00-16:30	2.6	3.6	10.4	9.4	26
16:40-17:10	3.0	4.2	12.0	10.8	30
18:00-18:30	3.2	4.5	12.8	11.5	32
Total (%)**	**2.2**	**3.0**	**8.6**	**7.8**	**21.6**

*Based on lane volumes from Table 10.

**Percent of total lane changes observed during six hours of sampling

Table 12: Speed Data[Location (1) -Inner Portion]

A.M. Peak (8:00)

SPEED GROUP km/h	MEAN SPEED OF GROUP km/h	NUMBEROF VEHICLES IN GROUP, f	% OF TOTAL OBSERVATION IN GROUP	CUMULATIVE OF TOTAL OBSERVATIONS
30-34.9	32.5	7	3.5	3.5
35-39.9	37.5	21	10.5	14.0
40-44.9	42.5	42	21.0	35.0
45-49.9	47.5	38	19.0	54.0
50-54.9	52.5	50	25.0	79.0
55-59.9	57.5	16	8.0	87.0
60-64.9	62.5	16	8.0	95.0
65-69.9	67.5	8	4.0	99.0
70-74.9	72.5	2	1.0	100.0
Totals		**200**	**100**	

P.M. Peak (16:00)

SPEED GROUP km/h	MEAN SPEED OF GROUP , km/h	NUMBER OF VEHICLES IN GROUP, f	% OF TOTAL OBSERVATION IN GROUP	CUMULATIVE %OF TOTAL OBSERVATIONS
30-34.9	32.5	7	3.5	3.5
35-39.9	37.5	11	5.5	9.0
40-44.9	42.5	31	15.5	24.5
45-49.9	47.5	38	19.0	43.5
50-54.9	52.5	56	28.0	71.5
55-59.9	57.5	22	11.0	82.5
60-64.9	62.5	20	10.0	92.5
65-69.9	67.5	10	5.0	97.5
70-74.9	72.5	5	2.5	100.0
Totals		**200**	**100**	

Table 13: Speed Data [Location (1) -Outer Portion]

SPEED GROUP km/h	MEAN SPEED OF GROUP, km/h	NUMBER OF VEHICLES IN GROUP, f	% OF TOTAL OBSERVATION IN GROUP	CUMULATIVE % OF TOTAL OBSERVATIONS
A.M. Peak(8:00)				
25-29.9	27.5	0	2.5	3
30-34.9	32.5	12	6.0	8.5
35-39.9	37.5	16	8.0	16.5
40-44.9	42.5	35	17.5	34.0
45-49.9	47.5	28	14.0	48.0
50-54.9	52.5	40	20.0	68.0
55-59.9	57.5	25	12.5	80.5
60-64.9	62.5	25	12.5	93.0
65-69.9	67.5	12	6.0	99.0
70-74.9	72.5	2	1.0	100.0
Totals		**200**	**100**	
P.M. Peak(16:00)				
SPEED GROUP km/h	**MEAN SPEED OF GROUP, km/h**	**NUMBER OF VEHICLES IN GROUP, f**	**% OF TOTAL OBSERVATION IN GROUP**	**CUMULATIVE % OF TOTAL OBSERVATIONS**
30-34.9	32.5	2	1.0	1.0
35-39.9	37.5	12	6.0	7.0
40-44.9	42.5	30	15.0	22.0
45-49.9	47.5	31	15.5	37.5
50-54.9	52.5	55	27.5	65.0
55-59.9	57.5	30	15.0	80.0
60-64.9	62.5	20	10.0	90.0
65-69.9	67.5	16	8.0	98.0
70-74.9	72.5	4	2.0	100.0
Totals		**200**	**100**	

Table 14: Time Headways

Location (1) - Inner Portion

A.M. Peak (8:00)	Lanes		
	1	2	3
Mean	4.9	5.4	6.8
Standard Deviation	5.5	6.7	7.9
Numbered Observed	55	48	37
P.M. Peak (16:00)			
Mean	4.3	4.7	6
Standard Deviation	5.1	6.3	6.9
Numbered Observed	60	51	39
Location (1) - Outer Portion			
A.M. Peak (8:00)	Lanes		
	1	2	3
Mean	4.5	6.7	6.9
Standard Deviation	6.1	6.8	8.2
Numbered Observed	54	53	44
P.M. Peak (16:00)			
Mean	4.4	4.9	6.4
Standard Deviation	5.2	6.1	7
Numbered Observed	59	50	40

2.2. Specify Problems (Function B)

Data gathered in Function (A) can be directed towards the solution of different problems associated with the location. Site features can be identified and classified as either object conditions or situation hazards. Traffic performance is very important to identify inefficient operations. **Table15** lists the hazards and inefficiencies along with their indicators.

2.3. Define Driver Performance Factors (Function C)

Driver performance factors were analyzed depending on the problem identified in Function (B), and the actual performance reflected by the data gathered in Function (A). A trace analysis was performed using the manual observations obtained during the collection of performance data. The target paths were all the traveled lanes in the location, for both inner and outer portions of the location.

Vehicles action along these paths was observed at a.m. and p.m. peak hours on Sunday at the two portions. The lane change actions from: left, right and middle were recorded. **Fig.7** summarized the results of the trace analysis.

In the inner part of the location, high-frequency maneuvers were observed where vehicles moved from the right lane to the middle lane (7.5%), and from the middle lane to the left lane (6.1%), creating a particularly hazardous situation. Additionally, vehicles moved from the left lane to the middle lane (2.2%) and from the middle lane to the right lane (4.5%). In the outer part of the location, lane changes included moving from the right lane to the middle lane (8.6%), and from the middle lane to the left lane (7.8%), also representing a dangerous situation, as well as from the left lane to the middle lane (2.2%) and from the middle lane to the right lane (3%).The results of the expectancy analysis are shown in **Table 16**, while **Table 17** outlines characteristics of expectancy violations.

The results of these analyses show two major violations:

(i) Driving in a high speed with limited sight distance; and

(ii) Carelessness in not watching for pedestrians crossing location can lead to conflicts.

These violations may give indicators of run-over (pedestrian) accidents through the link, especially at location (1) under consideration (see **Fig.4**). **Table 18** shows the detection and recognition analysis results.

The pedestrian accidents involve only a recognition problem to negotiate with the site view (HSS, 2020). The information needs derived for recognition will have a high severity designation because of the accident type that happened.

There is no loading area of information, presented to the motorists as he travels, through the location, and reflects the loss of this information that the driver actually needs to cope with the scene during his navigate on. This concept is clear near the merging area where the vehicles are always colliding with each other, or turning out of the street. Pedestrian collision due to user violations near the area are mostly due to high speed of traffic, on street vehicles loss of pedestrian crossing places and lighting sources at night there.

Negative driving behavior, which is significantly impacted by traffic conditions and infrastructure, among other factors, is a major contributor to traffic accidents (Mohsen Hosseinian & Najafi Moghaddam Gilani, 2020; Sharma & Sebastian, 2019).

2.4. Define Information Requirements (Function D)

The results from sections B and C indicate that the majority of location issues occur near U-turns, because street geometrics are changing, and accidents that took place here were mostly pedestrian collisions. Detailed analyses of observations by driving through the site show that there are dangers in these locations due to these U turns. **Table 19** contains the information need statements summarized from the preceding analyses. Problems needing aiding are described in this exhibit. The information needs to be thought to solve the problem, and the area in which the motorist needs that information is indicated as well.

Table 20 presents the assignment of primacy to each information need. As shown from the condition diagram (**Fig.3**), there is small information carried in this location and additional street and environment sources further complicate this information situation. The primacy needs to receive dominant treatment.

2.5. Determine Positive Guidance Information (Function E)

Table 21 denotes both the improvements needed in the current information system and the applicable traffic control devices. Some nonstandard devices are depicted. **Fig.8** shows some other developments needed around the street path to aid the proposed control devices to work more efficiently and to enhance safety along the entire street link.

Table 15: Hazard and Inefficiencies

Class	Description	Indicator	Severity Rank
Fixed Object	-Guardrails. -Sign Support. -Curbs.	- - -	- - -
Moving Object	-Sudden or late changes. -Illegal lane changes.	Accidents Accidents and observations	Moderate High
Condition	-U turns. -Sight obstruction. -Merging of Minor streets with the major street.	Accidents and observations observations Accidents	High High High
Situation	-Intersection of minor streets with the street with merging conflicts and limited sight distance. -Sudden brakes at location (1) due to high speed traffic from left lanes. -pedestrians crossing illegally. -Curb parking. -No information to drivers about the downstream conditions of the U- turns and merging area.	Accidents and observations Accidents and observations Accidents and observations observations observations	Moderate High High Moderate Moderate
Inefficiencies	- Conflicts in the shape of brake lightings, horns and erratic maneuvers. -Hesitations and unexpected situation especially at peak hours.	Accidents and observations observations	High High

Table 16: Expectancy Analysis

Location	Description	Driver Response	Expectancy Status	Violations
U turns	For turning vehicles with no speed change lanes-Pedestrian Crosswalks and guardrails are unavailable -availability of trees on the median between two portions	-Reduction in speed or changing lane due to slow vehicles turning or some parking vehicles and pedestrian crossings in between	-Expects that the street is free from congestion -Expects no more obstructions on the street -Doesn't expect pedestrian crossings	-Driver has inadequate warning of frequent midblock crossings -Pedestrians walking on roadway -Doesn't expect that the turn vehicles will force him to change his speed to the inside lane
Merging area	Side street merges the main street with no speed change lane	-Increase the speed when entering the merging area with change to the left lane flow to make U turn -Drivers in the upstream must watch the merging traffic and be unaffected by its movement	-Expects that he has enough speed to accelerate to reach his designation and make U turn -Driver in upstream expects waiting of merging traffic -Doesn't expect pedestrian crossings	-Drivers don't maintain in their driving in the same lane considering that is allowed, and no warning sign is their indicating the speed limitations before the merging area -Drivers may not be able to anticipate the merging area sign warning of the condition is needed before the merging area. -Drivers have inadequate warning of frequent pedestrian movement in the merging area.

Table 17: Expectancy Violation Characterization

Source	Characterization	Performance Impact			Information needs
		Speed	Path	Direction	
Traffic Control Devices (Misleading or incomplete information)	-The appearance of the merging area and U turns are surprises	X	X		-Drivers should be warned about this danger by a yellow solid line marking a long left and right shoulders -Special warning before the merge area and U turns must be fixed to warn drivers about the merging and turning vehicles -Speed limit sign before the merging area and U turns should be provided
	-Marking showing that overtaking is impermissible between the three lanes along all the sections for both directions.	X	X		-Solid yellow line marking of 25 cm width must be painted to warn drivers not to pass over or change their lane in both directions
	-No warning is given to the motorists about the pedestrian crossings	X	X		-Warning sign provided and its position should be convenient for drivers to see it.
Street Geometry (Acceleration and deceleration lanes)	-Unavailability of speed change lanes at U turns and merging areas cause problem with turning and merging vehicles.	X	X		-Providing speed change lanes (acceleration and deceleration lanes) by flattering the street at both sides of the U turns and at merging area -Drivers should be warned about this with a proper sign.
Traffic Flow (Erratic maneuvers)	-Drivers may not expect other vehicles to change their directions and sudden increase in traffic density at the merging area and near the U turns causing traffic maneuvers, horns, some delay in the traffic stream, and brake lighting.	X	X	X	-Speed limitations and markings at U turns and merging areas will warn the drivers not to overtake each other -Restrict on- street parking near these locations.
Environment (Weather)	-Wet conditions amplify the above situation and cause serious problems	X			-Provide adequate drainage -Warn drivers about the hazard of slippery when wet.

Table 18: Description of Detection and Recognition Problems

No.	Hazard	Detection and Recognition Problem	Compensation Information
1.	**Illegal pedestrian crossings**	Detection: Illegal crossings of pedestrians Recognition: Conflicts in the shape of brake lightings, horns, erratic maneuvers	-Install pedestrian cross walks -Install Guardrails -Warn drivers of pedestrian crossings by suitable signs.
2.	**Illegal parking**	Detection: Illegal on street parking of vehicles on right hand lane for both directions of the location with suddenly stopped buses. Recognition: Increasing density and changing of lanes by drivers at these locations.	-Prohibit on- street parking near U turns and merging areas -Widening the right lanes at separate places for bus stop.
3.	**Illegal lane changes**	Detection: Conflicting of high speed vehicles with vehicles making U- turns. Recognition: Trees in medians near the U- turns cause sight confusion and sight obstruction before and after the U turns and the traffic reduces its speed in the congested periods some lane changes and conflicts take place.	-Provide speed change lanes at the U turns -Install and improve pavement markings -Reducing the speed limit -Removing and cleaning the median near the U turns by cutting the trees.
4.	**Merging areas**	Detection: Unavailability of speed change lanes at merging areas. Recognition: Reducing speed of traffic and form conflicts with sudden turning traffics at side streets.	-Provide acceleration and deceleration lanes. -Reducing the speed limit. -Warn the drivers to the merging areas and crossing of side streets by suitable signs.

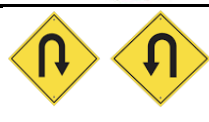
Table 19: Information need Statements

Location	Location Description	Driver Performance	Problem Requiring Aiding	Information needs	Location
1.Merging area	Side street meet the section	Overtaking and non-expectation of side street flow and pedestrian crossings	-Merging area is not clear and safe for drivers running at high speed. -Various types of conflicts with a gap for some users to cross at the merging area. -Unavailability of speed change lanes for the storage of turning vehicles. - Unavailability of pedestrian crossing location and guardrails around this location.	-Warning about the condition merging area -Speed warning sign before the merging area -Warn users not to cross the street -Warning sign that passing isn't allowed -Widening of merging area for proper and safe merging and passing.	-Upstream of the merging area and down stream.
2- U turns	Two U turns at the studied location for turning vehicles	Path selection with overtaking and erratic maneuvers and non-expectation of turning vehicles and pedestrian crossings	-Unavailability of speed change lanes -Many trees in the median near U turns obstruct vision -Driver has inadequate warning of frequent mid-block crossings due to unavailability of pedestrian crosswalk locations and guardrails.	-Advance warning of turning -Warn users not to cross the street and prevent crossing by installing guardrails. Install pedestrian crossing locations and pedestrian barriers -Install warrant and speed reduction signs -Install speed change lanes and widening for bus stop.	Before the U turns at the upstream and downstream.

Table 20: Information Needs Primacy Assignment

No.	Information Needs	Level of Driver Performance	Severity	Frequency	Primacy
1	Warn driver to pedestrian crossing at pedestrian crossing locations after installation of these locations.	Guidance	High	High	High
2	Warn pedestrian do not cross the section outside the crossing locations.	Guidance	High	High	High
3	Advance warning of merging areas or U-turns.	Guidance	High	Moderate	High
4	Solid Yellow lines between lanes to prevent overtaking.	Guidance	High	High	High
5	Provide Guardrails at the merging areas and turning locations with suitable materials.	Protection	Moderate	High	Moderate
6	Warn no pedestrian zone, or close the merging areas.	Navigational	High	Low	High
7	Warn the driver to KEEP RIGHT before U-turns.	Guidance	High	Low	High
8	Warn the driver to DON'T STOP at or near the merging areas or around the U turn places.	Guidance	High	High	High
9	Warn people by DON'T WALK sign along the section especially near the merging areas and U turns.	Protection	Moderate	Low	Moderate
10	Warn the driver to bus stop locations.	Navigational	Moderate	Moderate	Moderate

Table 21: Applicable Control Devices

Control Devices	Information Needs
	1. Warn driver to the pedestrian crossing at pedestrian crossing locations after installation of these locations
	2. Warn pedestrians not to cross the section outside the crossing locations
	3. Advance warning of merging areas or U turns
	4. Warn no pedestrian zone, or close the merging areas
	5. Warn driver to KEEP RIGHT before U turns
	6. Warn driver to DON'T STOP at or near the merging areas or around the U turn places
	7. Warn people by DON'T WALK sign along the section especially near the merging areas and U turns
	8. Warn driver to bus stop locations
	9. Warn driver for no passing(passing is prohibited)
	10. Indicate the U tern is ahead

3. CONCLUSIONS

The key conclusions drawn from this study are as bellow:

1. This study shows that identifying the factors leading to accidents is a highly complex process. It requires proactive measures to systematically address and reduce accidents in specific sections, aiming for a significant reduction in road accidents in the future.
2. The study involved characterizing the accidents, diagnosing the issues, and assessing field conditions to identify contributing factors. It then proposed countermeasures that, if implemented, could substantially enhance safety.
3. The procedure, initiated by the FHWA are fully applied during the field study phase for Kurdistan Street Section, has proven to be very effective in diagnosing and providing optimal solutions for the site.
4. Analysis of accident data from this problematic street section, using the SPSS computer package over a three-year period (2020-2022), revealed 67 accidents—about 5.3% of total accidents in the Erbil Street Network. The highest frequency of accidents occurred during morning and afternoon peak hours, specifically at 9:00-10:00 a.m. (14 of 67) and 14:00, 15:00, and 18:00 p.m. (21 of 67). Additionally, June and July had the highest number of accidents (18 of 67), with Saturdays and Sundays having the most accidents (13 and 14 out of 67, respectively), and

Wednesdays also showing a high number (13 out of 67).

5. Runover (pedestrian) accidents were the most common type (53 out of 67), resulting in 4 deaths and 52 injuries during the study period. Injury accidents were the predominant type overall (55 out of 67).
6. Vehicles speed generally exceeded the average speed for the link, which was measured by moving vehicle technique as 39 km/h;
7. Observing various types of conflicts at an intersection can help describe accident behavior during a detailed site analysis.
8. Condition diagrams for locations requiring further investigation can sometimes usable for fixing improvements without need for an extensive site investigation.

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