



Factors Affecting Traffic Accidents Density on Selected Multilane Rural Highways

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Abstract

Estimations of average crash density as a function of traffic elements and characteristics can be used for making good decisions relating to planning, designing, operating, and maintaining roadway networks. This study describes the relationships between total, collision, turnover, and runover accident densities with factors such as hourly traffic flow and average spot speed on multilane rural highways in Iraq. The study is based on data collected from two sources: police stations and traffic surveys. Three highways are selected in Wassit governorate as a case study to cover the studied locations of the accidents. Three highways are selected in Wassit governorate as a case study to cover the studied locations of the accidents. The selection includes Kut-Suwer, Kut-ShekhSaad, and Kut-Hay multilane divided highways located in the south of Iraq. The preliminary presentation of the studied highways was performed using Geographic Information System (GIS) software. Data collection was done to obtain crash numbers and types over five years with their locations, hourly traffic flow, and average spot speed and define roadway segments lengths of crash locations. The cumulative speed distribution curves introduce that the spot speed spectrum for each highway's whole traffic extends over a relatively wide range, indicating a maximum speed of 180 kph and a minimum speed of 30 kph. Multiple linear regression analysis is applied to the data using SPSS software to attain the relationships between the dependent variables and the independent variables to identify elements strongly correlated with crash densities. Four regression models are developed which verify good and strong statistical relationships between crash densities with the studied factors. The results show that traffic volume and driving speed have a significant impact on the crash densities. It means that there is a positive correlation between the single factors and crash occurrence. The higher volumes and the faster the driving speed, the more likely it is to crash. As the hourly traffic flow of automobile grows, the need for safe traffic facilities also extended.

Keywords: Traffic Safety; Accidents Density; Hourly Traffic Flow; Average Spot Speed; Multiple Linear Regression; GIS; Iraq.

1. Introduction

Every road accident is significant and essential. Traffic accident frequency has been increasing in Iraq in recent years, especially on rural roads. Road traffic crashes represent a severe problem threatening the world's societies, their well-being, and economies. In Iraq, like other countries, traffic crashes are one of the leading causes of death [1]. The answer to the question "Who is to blame"? Is usually more complex since more than one component must be

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considered when determining the cause of accidents. It may be the combination of two or sometimes all the three components: the driver, the roadway parameters and environment, and the vehicle.

A better understanding of the factors associated with crashes must be recognized to enable engineers to implement and identify operative countermeasures to reduce crash incidents. Many research and studies have shown to conclude the relations between factors connected with crashes and crash characteristics [2, 3]. The results of these researches have not been consistent, but strong suggestions from their data that severity and crash occurrences are greatly affected by speed-flow characteristics, such as average spot speed and Average Annual Daily Traffic (AADT). For example, worthy evidence suggests that a higher variation in vehicle speeds increases the occurrence of crashes in a traffic stream. The development of models for traffic accident density described by traffic stream data can assist the identification of hot spots and dangerous areas easily and objectively. This leads to indicate where effective countermeasures can be applied preferentially.

The problem of traffic accidents in Iraq has gained little attention as a field of scientific research. The police authorities have undertaken various legislative or along with the road actions as preventative means, but these are more or less based on personal judgments. Apart from the lack of a scientific background for some of those actions, they are efficient issues temporarily adopted to deal with specific situations. The road and traffic conditions in Iraq still need detailed investigation and revisions of design standards, especially in multilane rural highways. Several types of research have been implemented to relate hourly traffic volumes, geometric characteristics, the average speed with crash rates, and severities [4, 5].

Nevertheless, these researches have not recognized scientific relations that can be used to predict changes in accident characteristics because of the combined effects of changes in traffic flow and speed. The establishing of such mathematical models would considerably improve the efforts of traffic engineers to evaluate and determine suitable remedies and countermeasures to reduce the severity and occurrence of accident crashes. This study offers a starting point for the traffic crashes density prediction by validating national models, which could be employed in Iraq. The particular goal of the research is to examine and investigate the impact of the traffic volumes and vehicle speeds on the accident density.

The main purpose of this study is to recognize and identify the hourly traffic flow and average spot speed that significantly affect different types of crash density rates on multilane highways of Wasit governorate in Iraq and to find mathematical relationships which define and describe how these characteristics affect crash occurrence. The precise aims of the study are as follows:

- To investigate and determine mathematical relationships between collision, turnover, runover, and their total number of accidents density that occurred in Wasit governorate rural roads with traffic stream characteristics.
- To show the effect of hourly traffic flow and average spot speed on the traffic stream and accident density.

2. Materials and Methods

The methodology surveyed and followed in this study involved the following tasks:

- A review of the literature was accompanied to determine the influence of traffic characteristics and different types of crashes and crashes features;
- Data collection was done to obtain crash numbers and types and their locations, hourly traffic flow, and average spot speed and define roadway segment lengths of crash locations.
- Analyzing the accidents based on a surveying analysis during 2015-2019 considering; accident number, accident type, and accident location for each studied highway.
- The Geographic Information System (GIS) was used to visualize road traffic accident locations in the studied highways to understand the causes, relationships, patterns, and trends.
- Descriptive statistical analysis will be conducted to collect traffic data regarding the numbers, rates and behavior.
- Multiple linear regression analysis was carried out using the SPSS program and implemented to estimate the dependent variable – accident density rate – and the function of the independent variables – the hourly traffic flow and average spot speed. Regression helps determine the relationship between these variables and is mainly used in prediction studies to select the best model.

2.1. Variation of Crashes with Speed Characteristics

Speed is generally considered a traffic element. However, the fact that the driver has complete control of their vehicle and choosing the speed may introduce speeding as a human factor. When a crash occurs between two moving

vehicles, all kinetic energy must be dissipated mainly in the form of damage to both the vehicles and their occupants. The analysis of a traffic conflict between two vehicles as an inelastic impact reveals that the dissipated energy is proportional to the square of the relative speed vector. Accordingly, the severity of the conflict is significantly affected by the magnitude of each vehicle's speed and their angle of intersection [6].

The associated examinations [7, 8] also presented that driving speed is one of the highest causes of traffic crashes and the most operative factor for highway traffic accidents. Furthermore, some scholars carried out some investigation. Roque and Jalayer [9] suggest that single-vehicle accidents in rural open areas have a higher probability of mortality than accidents in urban areas due to the higher speed limits. Xie et al. [10] proposed that roadside accidents on interstate highways are more likely to be deadly, caused by the higher average spot speed. Researches had shown that the greater the average vehicle speed deviation, the higher probability of that vehicle being involved in a crash. This relationship is often referred to as being "U-shaped" and has been verified in research [11].

Furthermore, the most vulnerable road users—pedestrians, cyclists, and motorcyclists—have a high risk of severe or fatal injury when motor vehicles collide with them. The probability that a pedestrian will be killed if hit by a motor vehicle increases dramatically with speed. Figure 1, illustrates the likelihood of fatal injury for a pedestrian hit by a vehicle. The research indicates that while most pedestrians survive if hit by a car traveling 30 km/h, most are killed if hit by a vehicle traveling 50 km/h or more [12].

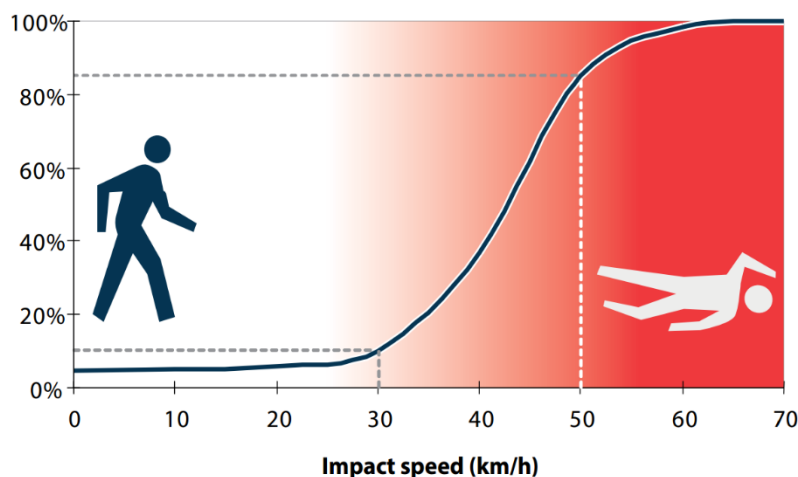


Figure 1. Probability of Fatal Injury for a Pedestrian Hit by a Vehicle [12]

2.2. Variation of Crashes with Traffic Volume

Of particular and specific interest is the effect of traffic conditions on accidents. A strong understanding of the relationship between traffic crashes and volume is necessary to improve traffic management and reduce crash frequency. The research stems from the 1930s, with relationships between crash occurrence and traffic volume/congestion falling into two broad categories: linear and non-linear [13, 14]. Generally, the relationship of speed with crashes cannot be defined without taking into account the simultaneous effect of other traffic characteristics such as traffic flow [11].

A crash prediction model can be represented by a graph, as shown in Figure 2. On the x-axis, the annual traffic volume (AADT) is plotted, and on the y-axis, the number of road crashes per kilometer. On the x-axis (AADT) of different intersections are displayed, which means that it does not represent an increased traffic volume of a single intersection [15].

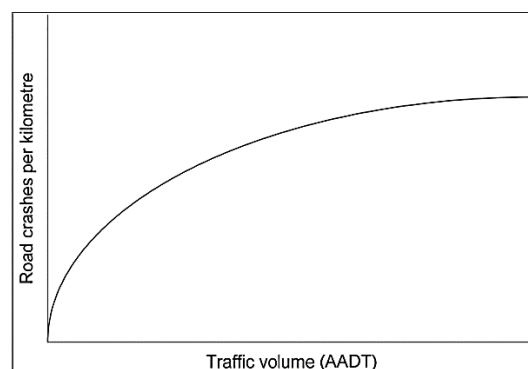


Figure 2. Graph of Crash Prediction Model [15]

The main aim of a study implemented for Romania's road network, one of the top countries in the EU Road Death Statistics, is to investigate state-of-the-art road accident research. The study offers a starting point for the crash anticipation by certifying an international mathematical model, which could be employed in Romania. The specific objective of the paper is to examine and investigate the influence of the traffic volumes on crash occurrence. The outcome was identified further in the research to highlight the correlation between traffic volumes and accidents through power regression. The results have proved the significant impact of traffic volumes in crash occurrence up to a definite congestion level [16].

2.3. Data Collection and Description

The data collection stage involved the next sub-tasks:

- Obtaining crash types data;
- Describing roadway segments of crashes locations;
- Attaining hourly traffic flow and average spot speed data.

Full descriptions regarding data, methods of collection, research methodology, and traffic survey are depicted in Figure 3. At the same time, collection of the accident data is a complex process because of the existing routine problems in country administrations, primarily due to the time restraint of the study. However, in this study, accident information has been gathered from two possible sources; reports made by traffic officers at the collision and statistical data from the Central Statistical Organization (CSO), Ministry of Planning, Republic of Iraq.

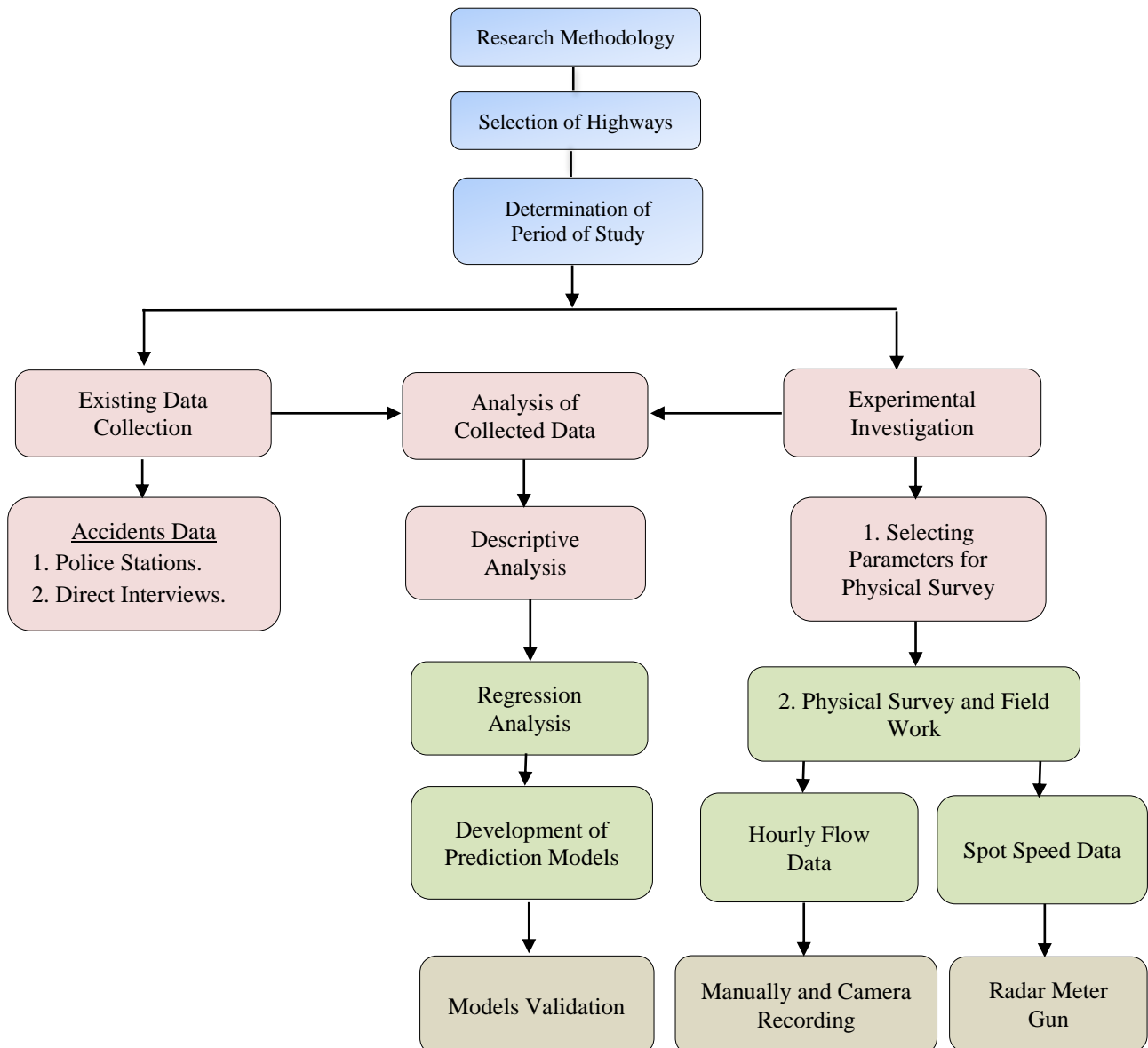


Figure 3. Plan of the Survey Program and Research Methodology

2.4. Selection of the Highways

Based on the scope of the study, the selection of the highways may depend on the available crash data and must be within the borders of the Wasit governorate in Iraq. The points considered during highways choice are:

- Asphalt surfaced multilane paved rural highways, which connect with Al Kut city representing the governorate's central official town.
- The length of the studied roads ranges between 40 and 100 km. This is mainly to get precise and specific traffic accidents, which will be determined from the police and traffic stations along these highways.
- Dense vehicles movement and frequent crash locations.
- Therefore, to conduct the present study, three multilane divided rural highways are selected for this study, which are:
- Kut–Suwera highway, 105 km length.
- Kut–Shekh Saad highway, 52 km length.
- Kut–Hay highway, 43 km length.

Figure 4 shows a GIS map that illustrates the administrative boundaries of the Wasit governorate and the general location of the studied highways. Furthermore, Figures 5 to 7 demonstrate the detailed and exact location for each studied highway.

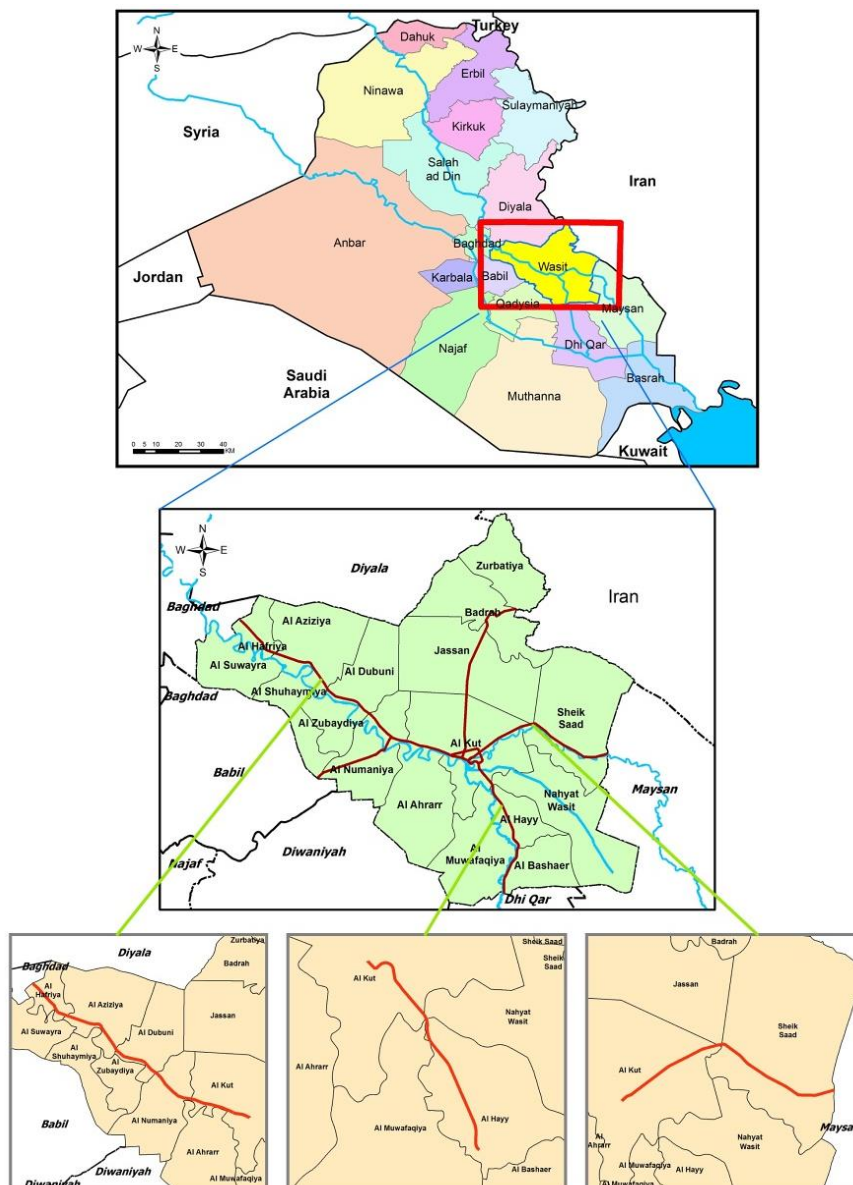


Figure 4. The Administrative Boundaries of Wasit Governorate Map Describes Studied Highways

In Iraq, highway (7) is a highway extending from Al Kut to Nasiriyah city. Kut–Hay highway is a part of this road. Kut–Suwera and Kut–Shekh Saad highways had number (6) in the coding system of the roads network in Iraq in which they are a part from Baghdad – Emara - Basrah highway. It radiates from Baghdad and provides access to Wasit in the southeast and Misan - Basrah in the south, with Kut city being the crossroads junction to Badra, Shekh Saad, and Hay cities. This highway is the most heavily used highway facility in Wasit.

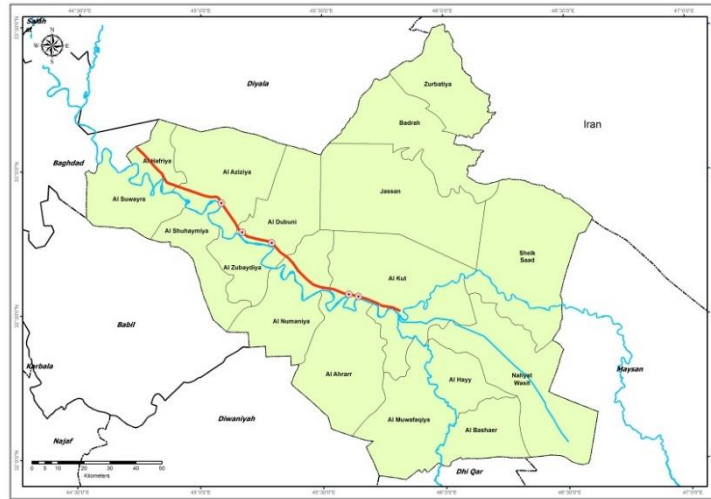


Figure 5. The Exact Location of Kut–Suwera highway

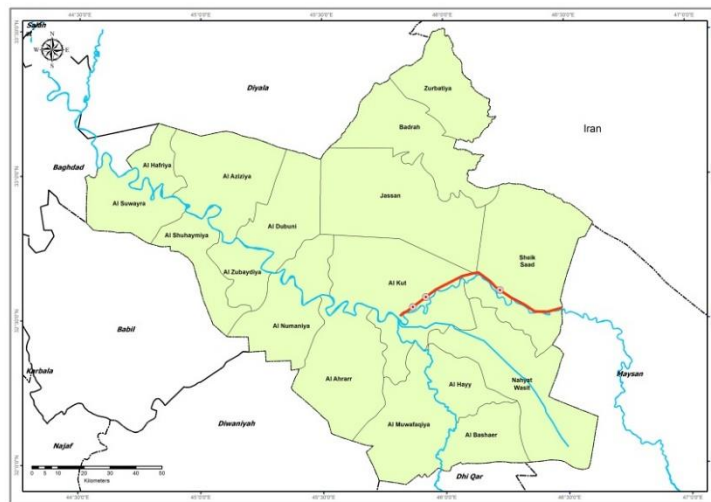


Figure 6. The Exact Location of Kut–Shekh Saad highway

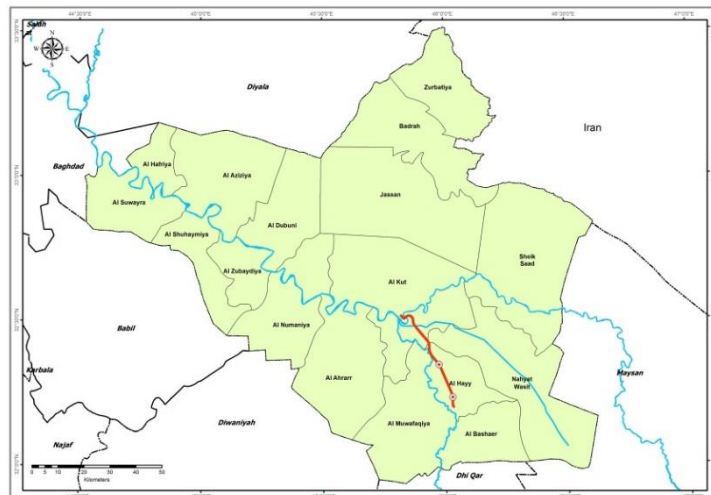


Figure 7. The Exact Location of Kut–Shekh Saad highway

In order to give adequate confidence in the study results, the information's about traffic crashes in Wasit Governorate presented herein was taken from the following authorities:

- The annual abstracts published by the Statistics Division in the Directorate General of Police;
- Central Statistics Organization (C.S.O);
- General Traffic Directorate;
- Crash files and reports in police and traffic stations;

The police stations involved in this study were distributed from Wasit Police Directorate as follows:

- For Kut–Suwera highway, four police stations were visited, which are: Al Balda, Al Salam, Al Debony, and Al Azezeya stations;
- For Kut–Shekh Saad highway, two police stations were involved which are: Al- Khelod, Shekh Saad stations;
- For Kut–Hay highway, two police stations were involved: Al- Falaheya, Al-Hay stations.

The data were obtained by checking out all the available files individually in all these stations. These files are just meant to keep the papers, which are supposed to make their way to court. Various meetings with the police personals and interviews with drivers were prepared to ensure some information about crashes location and severity. After analyzing all crashes reports, ten of places with their lengths are identified as crashes locations in which five, three, and two segments were recognized for Kut–Suwera, Kut–Shekh Saad, and Kut–Hay highways, respectively. Table 1 illustrates crashes segments names and locations.

Table 1. Crashes Locations for the Studied Highways

Highway Name	Segment Number	Location
Kut–Suwera highway	Seg.1	Al – Batar village
	Seg.2	Al Salam police station
	Seg.3	Al Debony district
	Seg.4	Al Zubaidiya intersection
	Seg.5	Al Azezeya city
Kut–Shekh Saad	Seg.6	White village
	Seg.7	Shekh Saad entrance
	Seg.8	River port district
Kut–Hay highway	Seg.9	Said Abdulatheem village
	Seg.10	Old brick kilns

By using the satellite image (quick bird) resolution, Figures 8 to 17 show the view of the studied segments and selected region of study, which will be needed on preparation the land-use layer and its corresponding spatial data of this study.



Figure 8. Seg1, Al Batar District



Figure 9. Seg2, Al Salam Police Station



Figure 10. Seg3, Al Debony District

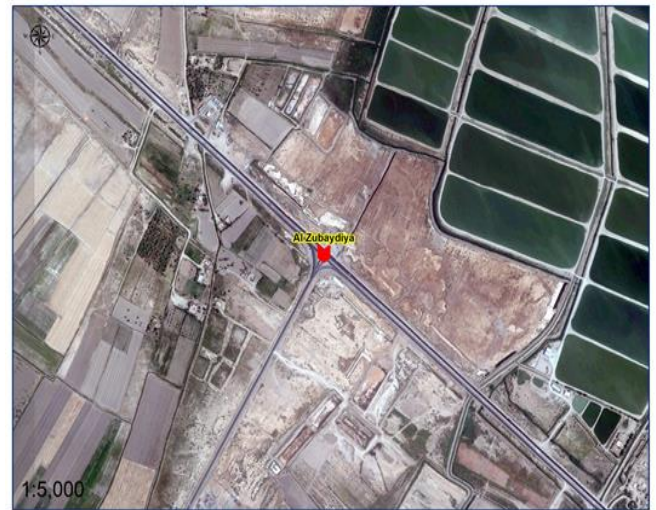


Figure 11. Seg4, Al Zubaidiya Entrance

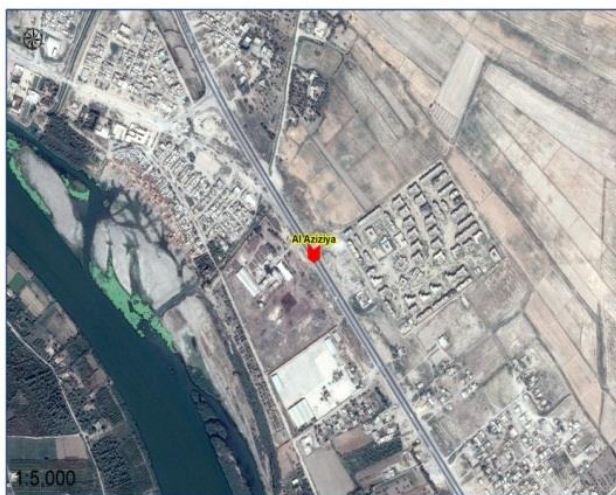


Figure 12. Seg5, Al Azezya District

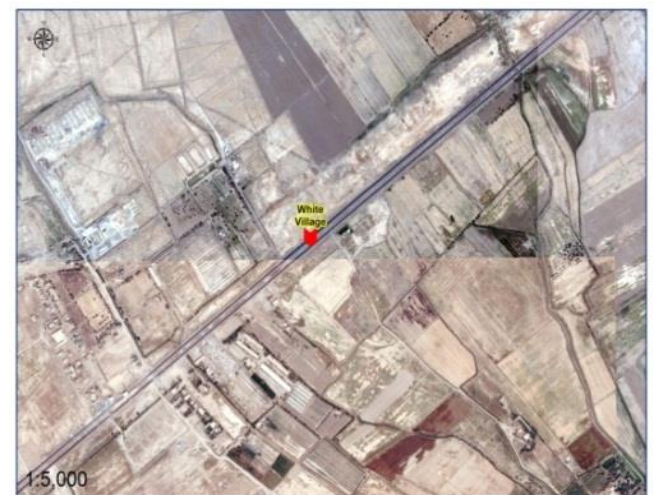


Figure 13. Seg6, White Village District

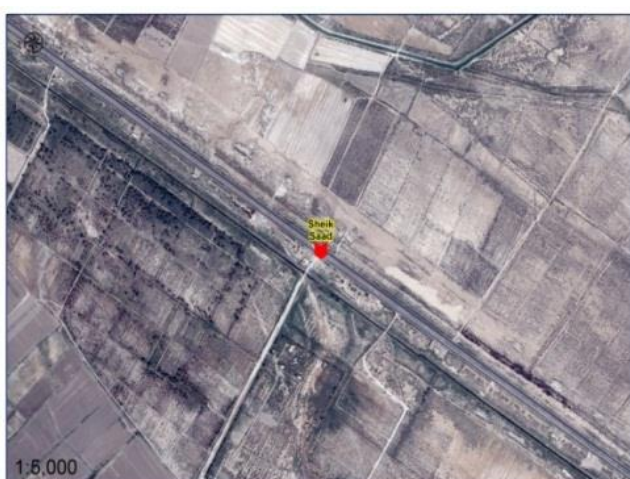


Figure 14. Seg7, Shekh Saad Entrance



Figure 15. Seg8, River Port District



Figure 16. Seg9, Said Abdulathem District

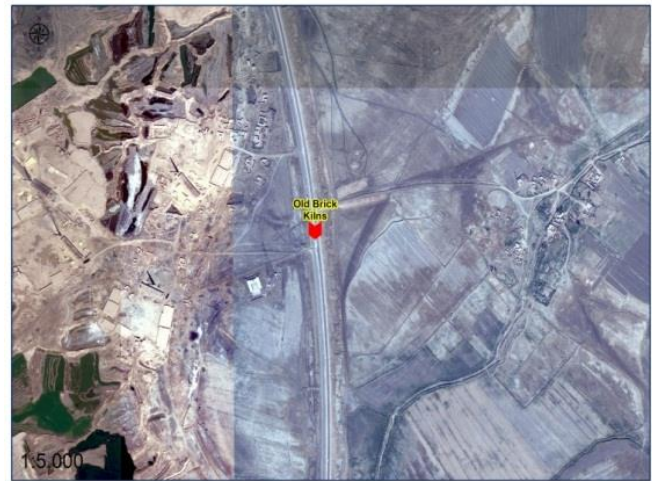


Figure 17. Seg10 Old Brick Kilns District

Luckily, accidents are rare events. Nevertheless, considering a statistical perspective, this necessitates analysis over long periods and wide spatial measures to confirm adequate and sufficient sample sizes. Huge datasets improve the sensitivity of model response to variables of interest. Reaching the targets of this study, it is preferred that a selected five-year interval is used to identify and predict crash models starting from 2015 and ending in 2019.

3. Crashes Data Survey

Similar to other developing countries, the main source of road accident data in Iraq is the police. According to the collected Iraqi crash form reports, the crashes are classified as per the type of crash into four major categories, namely: collision accident, turnover accident, run over accident, and others with fatal or non-fatal classification. The investigation report involves all related information to drivers, passengers, witnesses if available, vehicles, time, date, and location of an accident. Then, the accident report (which is filled by the traffic officer) has to be added to the investigation report and sent together to the court as litigation (law case). Many of the litigation regarding accidents do not involve accident reports because either the vehicles are removed from the crash location before the traffic officer arrives (s). Due to some reasons, the traffic officer(s) do not arrive at the accident scene.

Only weekday crashes were matched to weekday surveys to certify that comparable traffic and speed characteristics happened during the crashes. Reviewing and analyzing the collected, registered crash reports are presented in the following articles. Figure 18 shows the distribution of crashes by type for each year in the studied segments (2015 to 2019). As it can be seen from the figure, collision crashes comprise most crashes for the five studied years (except 2015) compared to the other crashes types. This may be attributed to the high interaction between speed and traffic volume, potential conflicts between turning vehicles, and road deficiencies characteristics on rural roadway sections.

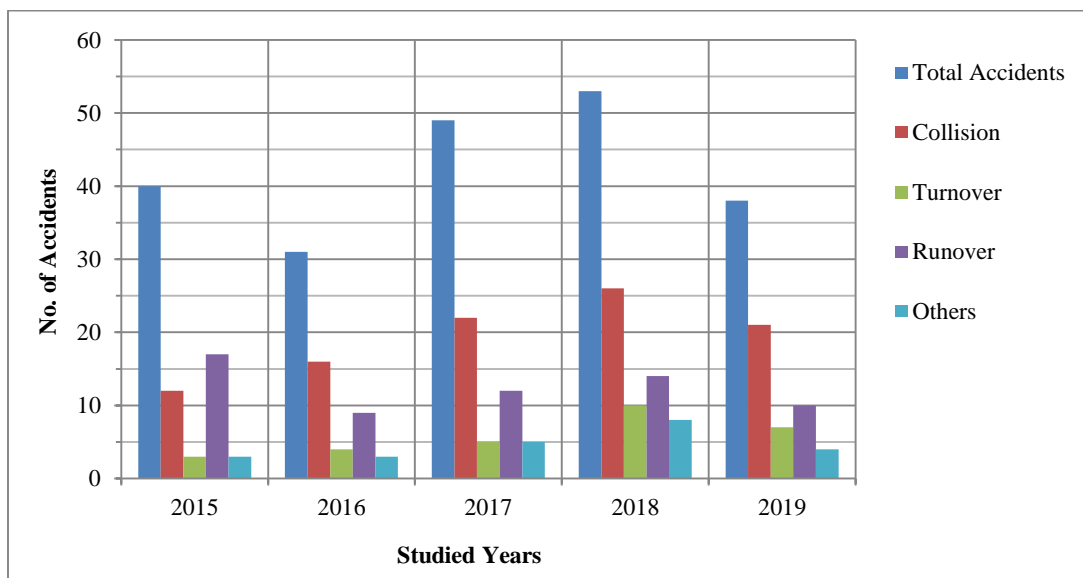


Figure 18. Crashes Distribution by Type and Year of Study

3.1. Spot Speed Survey

There are different ways of measuring spot speeds depending on the equipment available and the purpose of the study. The radar speed gun tool is used in this research, as shown in Figure 19.



Figure 19. Speed Gun Photo

Speed distribution is usually based on measuring the speeds of an adequate sample of vehicles passing the spot. Normally, the sample covers 50, preferably 100, vehicles. The hand held speed radar gun with moving mode was used in this speed study. A radar speed gun (also called radar gun and speed gun) is a Doppler radar unit that may be hand-held, vehicle-mounted, or static. It measures the speed of the objects at which it is pointed by detecting a change in frequency of the returned radar signal caused by the Doppler effect, whereby the frequency of the returned signal is increased in proportion to the object's speed of approach if the object is approaching, and lowered if the object is receding. Such devices are frequently used for speed limit enforcement.

The device was handled by observer who sitting in a car parked at the edge of the roadway and was directed at an angle of approximately 15 degrees with the centerline. Readings were taken for traffic in one direction only that considered the place of crashes from the crashes report list. Generally, for the speed study, peak hours will be included in all samples. The measurements were carried out on a fixed time interval basis (30 minutes), covering all vehicles passing the spots. Speeds were recorded for trucks, pick-ups, mini buses, big buses, and saloon cars. Data collection was done during daylight hours of work weekdays. Table 2 presents the statistical analysis of spot speed data for the selected segments of the study. For each study site, the following statistical terms were computed:

- Mean and Median;
- Standard deviation;
- Standard error of the sample mean;
- Coefficient of variation.

Table 2. Spot Speed Characteristics for the Studied Segments

Study Sites	Mean (kph)	Median (kph)	15th% (kph)	85th% (kph)	Standard Deviation (kph)	Standard Error of Mean (kph)	Coefficient of Variation (%)
Seg1	101	105	54	125	41.25	10.65	40.73
Seg2	105	113	57	125	47.98	11.99	45.4
Seg3	100	96	55	134	45.09	11.27	45
Seg4	104	104	53	135	47.99	11.99	46
Seg5	99	100	53	130	39.59	10.22	39.85
Seg6	97	92	55	120	44.11	11.02	45.18
Seg7	102	100	57	97	43.17	11.14	42
Seg8	97	97	60	117	41.65	10.41	42.8
Seg9	96	102	49	112	40.25	10.13	42
Seg10	99	100	60	150	45.15	11.28	45.55

The median is that speed where there are just as many vehicles going faster as are going slower. This value is obtained from the cumulative speed distribution curve by reading the speed, which corresponds to the 50% value. It is apparent from the table that a significant fluctuation in the median result can occur. In addition, a higher value of variation indicates a wider scatter about the mean and vice versa. It can thus be said that, for example, the speed data at segment10, where the coefficient of variation is equal to 45.55 %, is more dispersed than at the other sites.

Figures 20 to 22 showed the spot speed frequency distribution polygon cumulative curve for Kut–Suwera, Kut–Shekh Saad, and Kut–Hay) respectively. The cumulative speed distribution curves provide two major elements to be tackled for discussion, namely, 15 and 85% values.

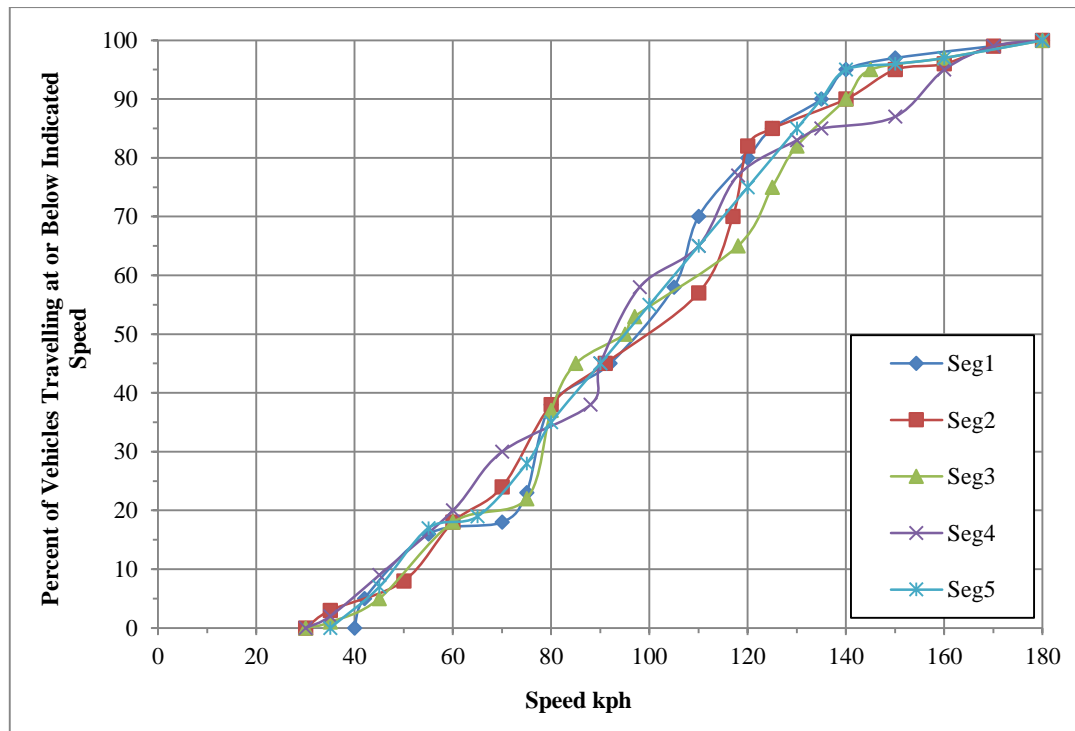


Figure 20. Cumulative Frequency Polygon Curve for (Kut–Suwera) Highway of Studied Segments

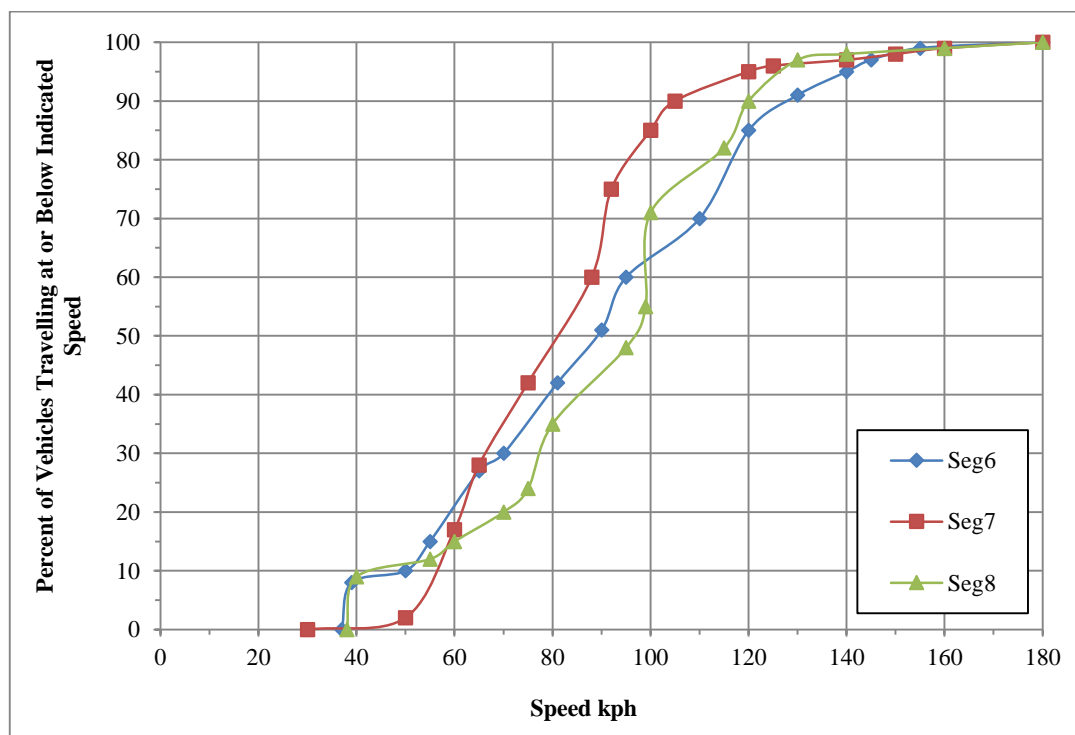


Figure 21. Cumulative Frequency Polygon Curve for (Kut–Shekh Saad) Highway of Studied Segments

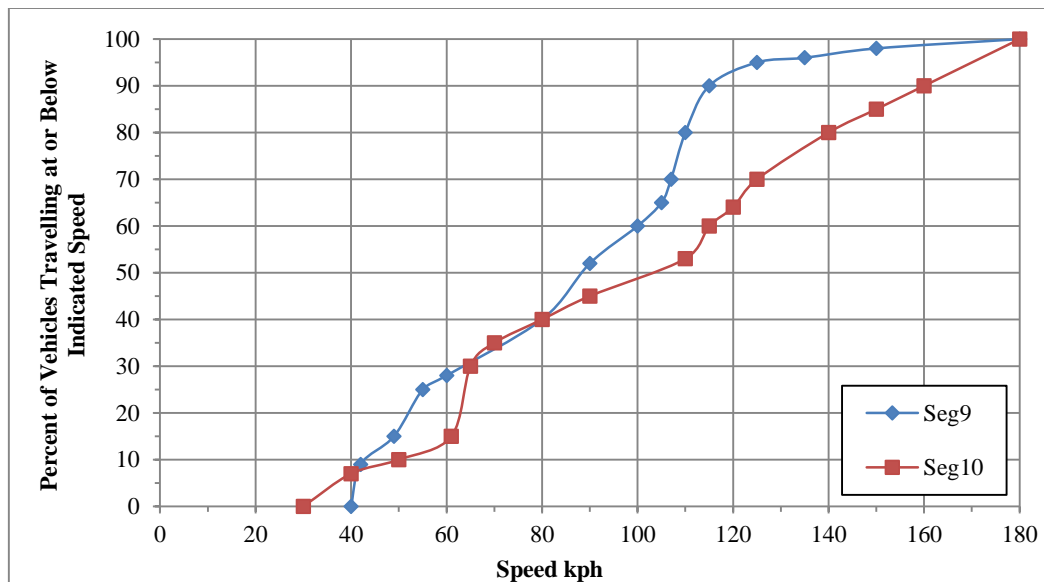


Figure 22. Cumulative Frequency Polygon Curve for (Kut-Hay) Highway of Studied Segments

3.2. Hourly Traffic Flow Survey

Traffic volumes have increased considerably over the years for the studied highways since 2000, possibly due to two factors. First is the overall increase in car ownership and consequently increase in travel, and secondly, is that these highways provide access to religious cities like Baghdad, Karbala, and Najaf where the holy shrines are located. Every Thursday and Friday as well at certain periods in the year, pilgrimage exerts huge traffic on the highways, especially along the section extending to Nummaneya city, which is a part of Kut-Suwera highway containing Seg1 and Seg2.

In addition to these impacts, the presence of the industrial establishments along Kut-Baghdad highway, brick kilns beside Kut-Hay highway, and large agricultural areas nearby Kut-Shakh Saad highway impose a heavy commercial and agricultural nature to the traffic stream, emphasized by the relatively high percentage of trucks in daily traffic. Manual counting involves one or more persons recording observed vehicles using a counter. Traffic flow counts are held continuously for a week covering all classes of vehicles in the traffic stream, which include passenger cars, buses, and trucks. Two Sony video cameras have been used to capture the field data. The selection of a vantage point was one of the most challenging things in line with getting security permission that was faced during the data collection stage. Footbridges have been selected as the best vantage point to monitor the traffic stream. Figures 23 to 25 present the daily variation in hourly traffic flow for the studied segments in Kut-Suwara, Kut-Shaikh Sadd, Kut-Hay highways, respectively, as revealed by the full week counting.

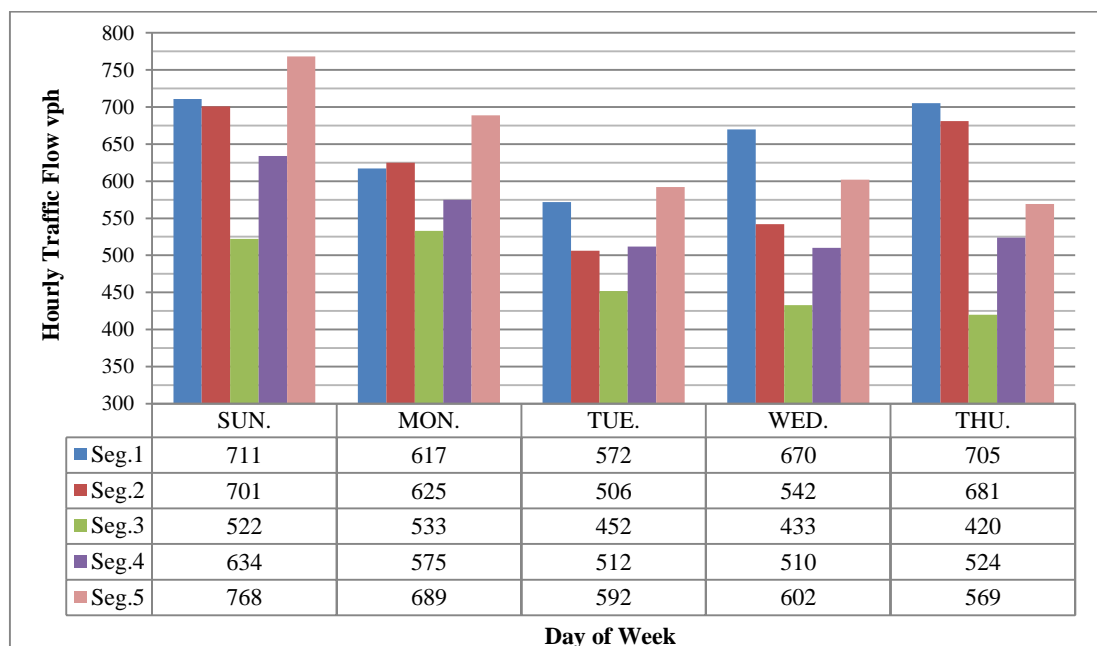


Figure 23. Daily Hourly Traffic Flow for Kut-Suwera Highway Segments

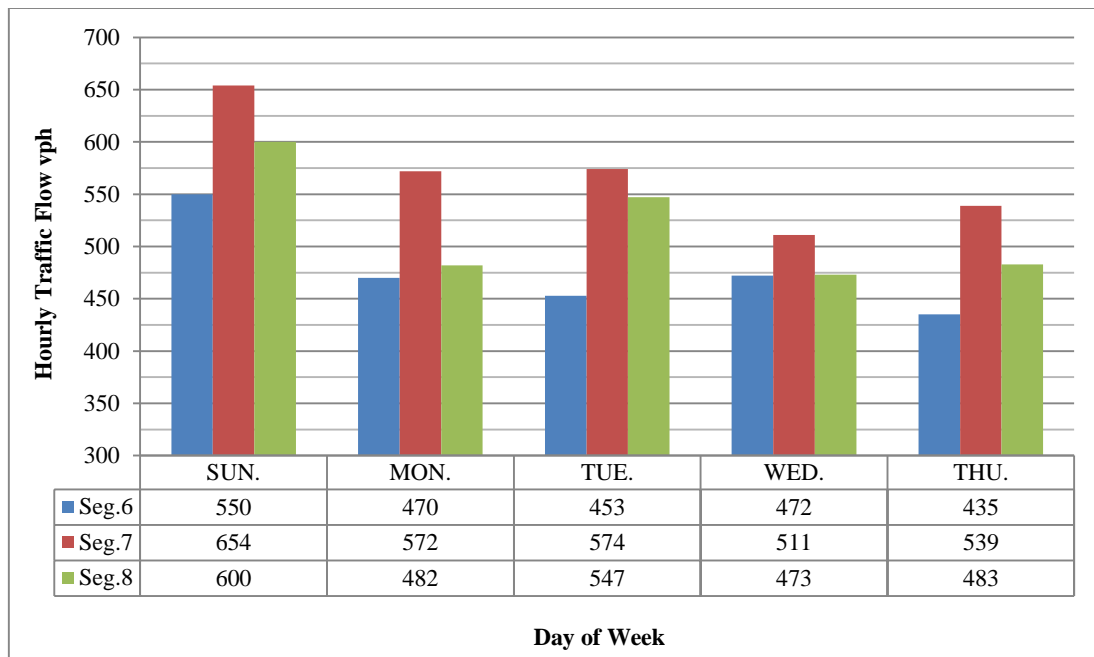


Figure 24. Daily Hourly Traffic Flow for Kut– Shekh Saad Highway Segments

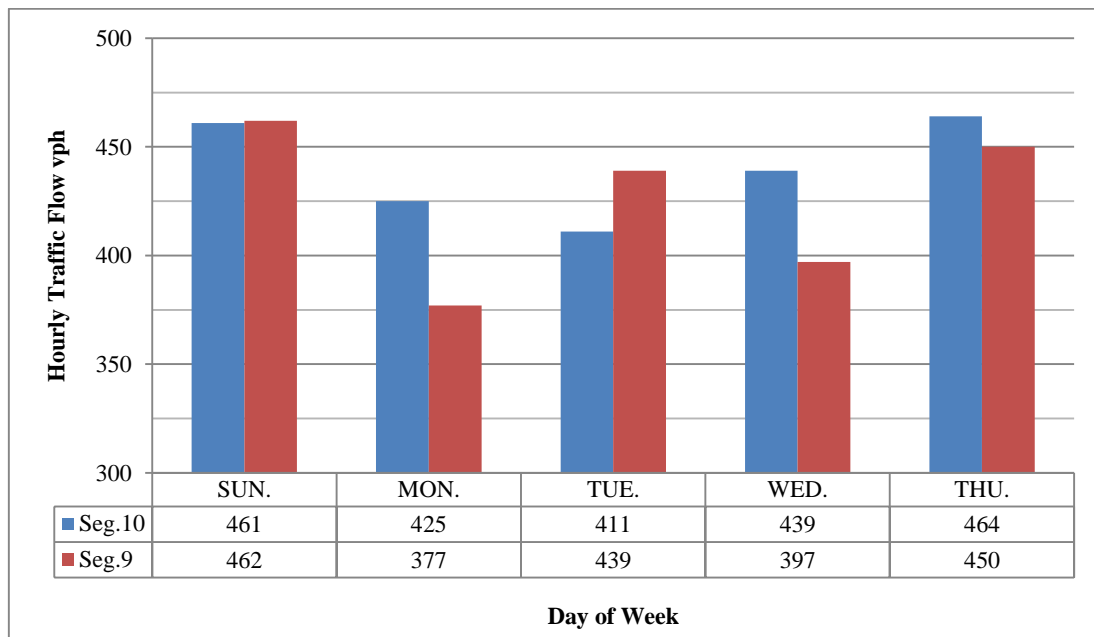


Figure 25. Daily Hourly Traffic Flow for Kut – Hay Highway Segments

Figures 23 and 25 trends indicate two distinguishable peaks for the studied segments on Sunday and Thursday. Two factors may play a major role in this interesting case in the traffic pattern. The first factor is the religious nature of Thursday day, in which a religious occasion for some Muslims was held on this day every week from the southern governorate s. That occasion caused a premature rise in traffic flow. The second factor is the beginning of the works at Sunday that contributed to the increase in traffic flow entering Baghdad, which is related to the people who live in the southern cities and from remote places are employed in Baghdad to join their work. It is obvious from Figure 24 that traffic volumes on Monday, Tuesday, Wednesday, and Thursday are approximately similar, but a peak is observed on Sunday.

3.3. Crashes Densities Rates by Highways And Segments

It is conducted to use crash density rates as the dependent variable in the statistical models in which crash frequencies are divided by segments length to provide densities for the studied kinds of accidents. This rate is typically calculated yearly. The following equation will be applied to obtain crash rates for black spot locations [17]:

$$\text{Accidents Density (Ad)} = \text{Acc.}/(L \times T) \quad (1)$$

Where: $Acc.$: the number of accidents that occurred on the section with length “ L ” (accident per mile per year); L : the length of the investigated road section (mile) and studied period (year); T : the number of studied years.

The main advantages of this method are:

- Both exposure factor and frequency factor are taken into account;
- It represents a relatively simple and direct method.

The value of crashes densities rate, when computed as an average over five years, should reduce the amount of chance variation in the data (or the experimental error that may tend to be significant when dealing with rural car accidents) and be used as the dependent variable of the suggested models. Table 3 shows the general crash density rates, which describe total crashes occurrence and their types in the studied sites.

Table 3. Accidents Densities by Type and Studied Segments.

Seg No.	Section Length (mile)	Total Accidents		Collision Accidents		Turnover Accidents		Runover Accidents	
		No.	Density	No.	Density	No.	Density	No.	Density
1	0.606	45	14.85	19	6.27	8	2.64	11	3.63
2	0.363	30	16.5	14	7.7	5	2.75	8	4.4
3	0.303	10	6.6	5	3.3	1	0.66	3	1.98
4	0.545	18	6.6	9	3.3	3	1.1	4	1.46
5	0.666	38	11.4	16	4.8	5	1.5	15	4.5
6	0.454	13	5.72	6	2.64	1	0.44	5	2.2
7	0.393	25	12.69	10	5.07	3	1.52	7	3.55
8	0.303	8	5.28	3	1.98	2	1.32	3	1.98
9	0.424	15	7.07	7	3.3	1	0.47	5	2.35
10	0.727	9	2.47	8	2.2	0	0	1	0.27

By the same meaning, Figure 26 summarizes and shows total, collision, turnover, and runover crash density rates. As crashes number, still segments (1 and 2) on Kut – Suwera highway are the most hazardous locations according to their total crashes rates.

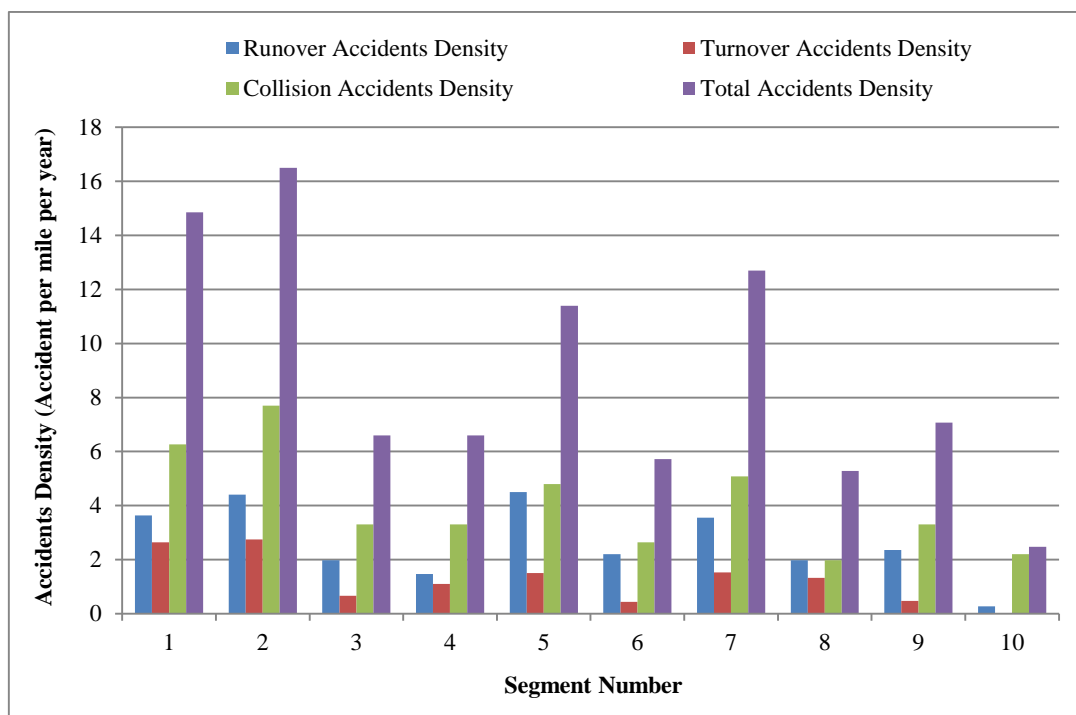


Figure 26. Crashes Densities Rates by type and Studied Segments

3.4. The Regression Analysis Techniques

The regression analysis technique is used to create a useful step-wise regression model that could be used to develop priority aspects for selecting the type of highway improvement. In order to save money, time, and effort, the statistical regression technique allows a researcher to evaluate independent or predictor variables. The easier and most important use of the technique is to find the best linear predictive model with a minimum number of independent variables. The overall accuracy of any predictive model in multiple linear regression analysis is described by the correlation coefficient (R) and coefficient of determination (R^2). Correlation is the mathematical expression used to definite the power and strength of the intensity or relationship between the dependent variant i.e., predicted accidents density – and the independent variable function i.e., observed accidents density. The predictive accuracy in absolute units is reflected by the standard error of estimation about the regression line.

The various elements of a multiple linear regression equation can be illustrated as follows:

$$Y = b_0 \pm b_1X_1 \pm b_2X_2 \pm b_3X_3 \dots\dots\dots \pm b_nX_n \quad (2)$$

Where: Y = dependent variable; b_0 = regression coefficient (sample intercept if any, or the value of the dependent variable when the independent variable is zero; b_n = regression coefficient of the n^{th} independent variable, and; x_n = quantified value, or the coefficient of the qualitative value of the n^{th} independent variable,

The dependent and independent variables that considered in this study isolated for each crash density type, which were examined in the models, were summarized and reported in Table 5 with their abbreviations.

Table 5. List of Variables Considered in Regression Analysis

Variables Type	Abbreviation	
Dependent Variables	Total Accidents Density	TAD
	Collision Accidents Density	CAD
	Turnover Accidents Density	TOAD
	Runover Accidents Density	RAD
Independent Variables	Hourly Traffic Flow (vph)	Flow
	Average Spot Speed (kph)	Speed

The descriptions of the statistical and regression analysis results are briefly discussed in the following paragraphs.

4. Models Development

The data were used and applied to the multiple linear regression models using the SPSS software package that states the mean of the dependent variable as a linear relationship of two predictor variables which are hourly traffic flow and average spot speed. By using the method of least squares, the models were fitted to the data, and a t-test was achieved and performed to test the resulting (regression coefficients) comparing with the null hypothesis of being equal to zero at the 5 % significance level. The adequacy of the fit was judged based on the R^2 value and the normality of the residuals.

A correlation analysis was carried out to determine independent variables that were correlated to each other. Correlated variables were not used together in any model. Average spot speed and hourly traffic flow data are selected and tested for correlation. The results indicate that a weak relation was detected between the two variables in which the correlation factor is equal to 0.571 with no significant effect ($p=0.085$). Table 6 illustrates the resulted linear models that consider hourly traffic flow and average spot speed of the studied segments as independent variables. This table reveals that some of the suggested models are highly correlated.

Table 6. Results of Regression Analysis Considering Segments Hourly Traffic Flow and Average Spot Speed

Densities Type	The Predicted Model	Correlation Factor (R)	Coefficient of Determination (R^2)	F-Value	P value
Total Accidents Density	TAD = -39.25 + 0.04 flow+ 0.2656 speed	0.840	0.706	8.412	0.014
Collision Accidents Density	CAD = -24.19+0.013 flow+0.214 speed	0.821	0.674	7.226	0.02
Turnover Accidents Density	TOAD = -8.266+0.009 flow+0.049 speed	0.891	0.793	13.42	0.004
Runover Accidents Density	RAD = 3.388+0.0151 flow-0.086 speed	0.808	0.653	6.57	0.025

Four developed models, which are (TAD, TOAD, CAD, and RAD), proved statistically for their significance at 5 % level and suggesting increasing numbers of crashes densities with rising levels of traffic flow. All of the models for each density type show similar trends. The positive relation implies that the increase of traffic flow will increase density rates and consequently their severity. This could be attributed to the fact that on multilane rural roads, conflicts due to wrong over taking, improper lane changing, following too closely, merging, and diverging when traffic increased provide no clearance that may encourage the drivers to deviate from their paths and make improper maneuvers. Therefore, the occurrence of crashes becomes possible. This confirms the finding of Vey (1939) [17] and Raff (1953) [18].

Some of the studies results are conflict with this behavior. While on the surface, it appears appropriate to reduce and decrease traffic flow, if it correlates negatively with accident frequency, a reduction may negatively affect road safety [19]. All of the models were found to be highly significant with a probability value (P) less than 0.05 and a coefficient of correlation (R) greater than (0.80). The R^2 value of 0.793 for TOAD model indicates that 79.3 percent of the variation in turnover crash density rates are explained by variation in traffic flow and spot speed values with a correlation factor of ($R = 0.891$). These results clearly show that changes in density rates are not necessarily caused by anyone independent factor but that these changes are a result of the combined effects of these independent factors and other unstudied factors.

The residual analysis assured that the models with (R^2) higher than 0.70 represent the situation well, as shown in Figures 27 to 30. Investigation of residual plots showed that the residuals were normally distributed and that the normality hypothesis inherent in the development of a linear regression model was not violated in which all data are meeting and collecting around the 45° straight line. It was therefore concluded that linear relationships could be used to describe the data obtained for Wassit governorate multilane road types. The collision density rate model is significant at the 0.02 level. This implies that the apparent relationship is expected purely by chance two in 100 times, if there is no relationship between the collision crash rate and traffic flow. The value of (F) explains the variance ratio statistic used to test the hypothesis that all of the partial regression coefficients on the independent variables in the model are zero.

For the runover accidents density models, a negative relationship was detected between crashes occurrence and average spot speed. This may be due to the fact that on rural dual carriageways, average spot speed is less effective on crashes, especially congested ones that restrict the driver to limit his vehicle speed and be more careful. Other contributing factors such as driver behavior, environmental conditions, and vehicle characteristics may be responsible for these accidents.

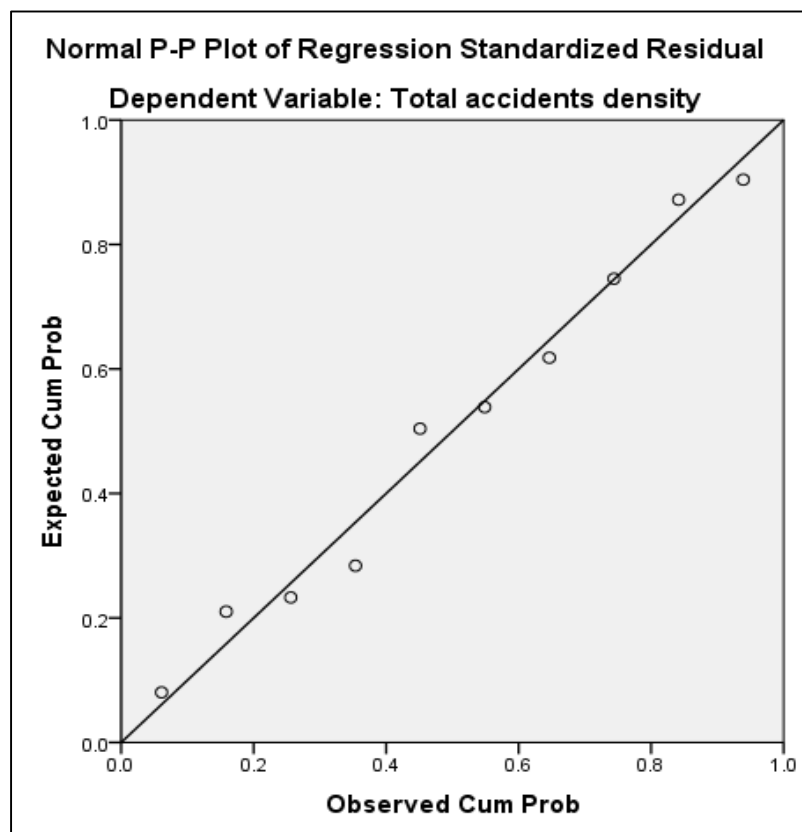


Figure 27. Normal p-p plot of regression residual for TAD model

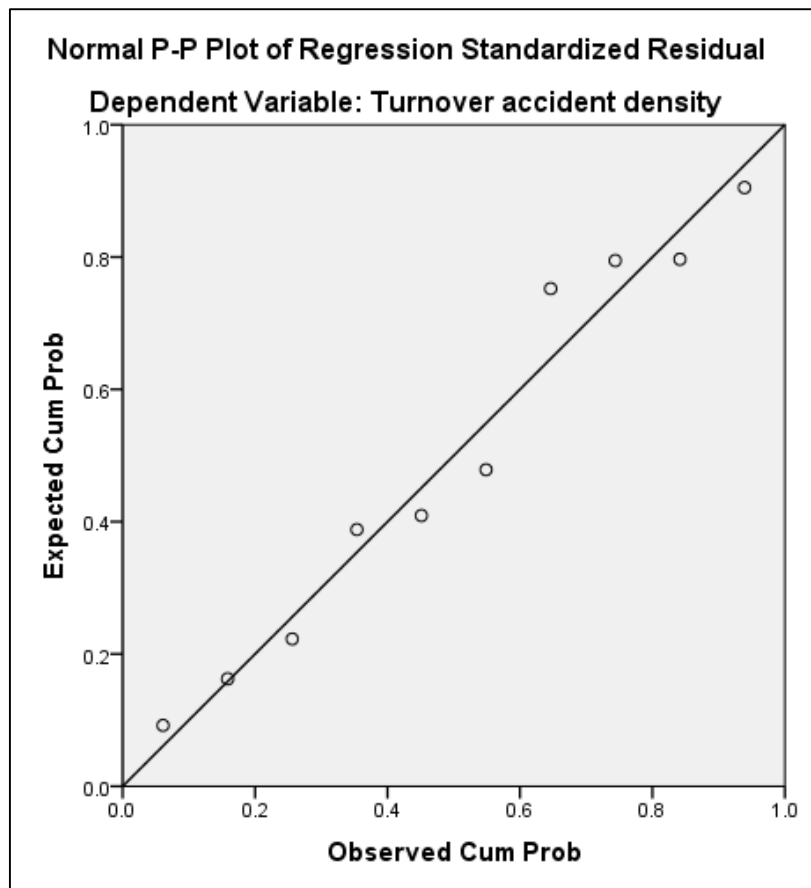


Figure 28. Normal p-p plot of regression residual for TOAD model

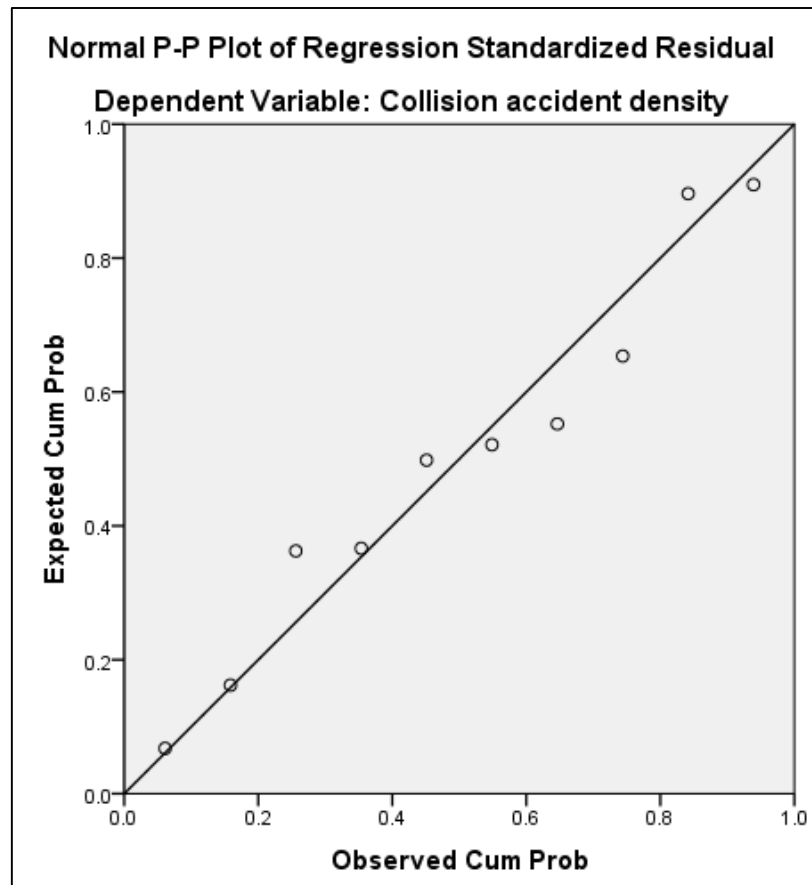


Figure 29. Normal p-p plot of regression residual for CAD model

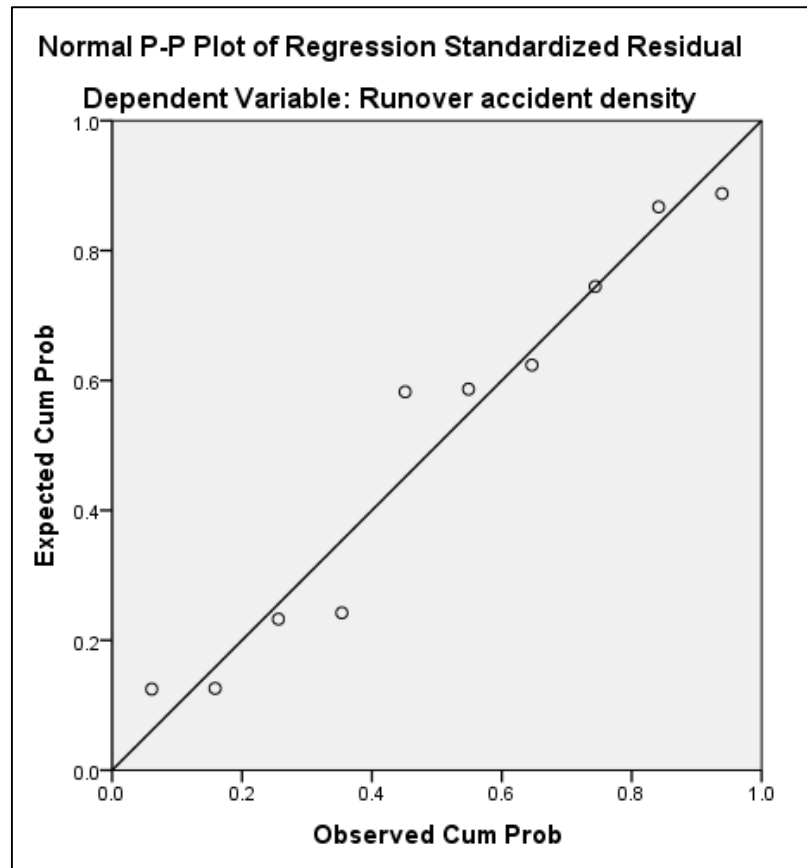


Figure 30. Normal p-p plot of regression residual for RAD model

5. Conclusions

This paper uses real data taken from the local traffic agency in Wassit Governorate / Iraq for the period from 2015 to 2019 to identify the relationship between accidents density and some of traffic flow elements. Based on the survey results and the subsequent analysis of data, the following conclusions can be summarized as follows:

- According to the traffic crashes types, the collision type produces a higher proportion 46% of total accidents. While the runover, turnover, and other kinds represent only 29, 14, and 11% of total crashes, respectively.
- Segments 1 and 2 on Kut–Suwera highway are the most hazardous locations according to their total crashes rates densities.
- As the hourly traffic flow of automobile grows, the need for safe traffic facilities also grown. Outcomes express that accident density increases linearly in the higher levels of traffic volume and average spot speed. Consequently, advising that managing traffic to avoid such high levels would have the greatest influence on reducing accident occurrence. Essentially, there is no observable and noticeable increase in accident density as traffic volume and vehicle speed decrease, meaning that reducing these two elements would not negatively affect public health.
- Significant relation at 5% level is found for TAD, TOAD, CAD, and RAD, models with average spot speed and hourly traffic flow, and these relationships can be adopted for this study.
- The linear regression equation for traffic flow and spot speed representation and relation to crashes occurrence was an acceptable and adequate model to use in modeling data on a number of road traffic accident densities within rural roads in Wasit governorate.

6. Declarations

6.1. Author Contributions

A.H.A. designed the study and conceived the presented idea; A.S.S. performed data collection and verified the analytical methods; Z.A.R. analyzed the data and wrote the manuscript in consultation with A.H.A. and the last encouraged Z.A.R. to investigate “the adopted mathematical models” and supervised the findings of this work. All authors have read and agreed to the published version of the manuscript.

6.2. Data Availability Statement

The data presented in this study are available in article.

6.3. Funding

This research received no external funding. It was sponsored by the “College of Engineering, Baghdad University, Ministry of Higher Education and Scientific Research of Iraq”, and “General State of highways and Bridges, Ministry of Housing and Construction in Iraq”.

6.4. Conflicts of Interest

The authors declare no conflict of interest.

7. References

- [1] Central Statistical Organization (C.S.O), "Statistics Roads Traffic Crashes in Iraq in 2018", Available online: <http://cosit.gov.iq/en/> (accessed on May 2021).
- [2] Rural and Urban Crashes: A Comparative Analysis. U.S. Department of Transportation Technical Report. DOTHS808450. (August 1996). Available online: <https://crashstats.nhtsa.dot.gov/Api/Public/Publication/96847> (accessed on March 2021).
- [3] Lassarre, S. "The Introduction of the Variables 'traffic Volume,' 'speed' and 'belt-Wearing' into a Predictive Model of the Severity of Accidents." *Accident Analysis & Prevention* 18, no. 2 (April 1986): 129–134. doi:10.1016/0001-4575(86)90057-6.
- [4] Lord, Dominique, Abdelaziz Manar, and Anna Vizioli. "Modeling Crash-Flow-Density and Crash-Flow-V/C Ratio Relationships for Rural and Urban Freeway Segments." *Accident Analysis & Prevention* 37, no. 1 (January 2005): 185–199. doi:10.1016/j.aap.2004.07.003.
- [5] Harwood, D. W. Relationships between Operational and Safety Considerations in Geometric Design Improvements. In *Transportation Research Record 1512*, TRB, National Research Council, Washington, D.C., (1995). Available online: <https://onlinepubs.trb.org/Onlinepubs/trr/1995/1512/1512-001.pdf> (accessed on May 2021).
- [6] Ghorbanzadeh, Mojgan. "A Study on the Quality of Campus Landscape on Students' Attendance at the University Campus." *Civil Engineering Journal* 5, no. 4 (2019): 950-962.
- [7] Letirand, Frédéric, and Patricia Delhomme. "Speed Behaviour as a Choice between Observing and Exceeding the Speed Limit." *Transportation Research Part F: Traffic Psychology and Behaviour* 8, no. 6 (November 2005): 481–492. doi:10.1016/j.trf.2005.06.002.
- [8] Bagheri Khalili, Fatemeh, Abdolreza Sheikholeslami, and Abbas Mahmoudabadi. "Variable Efficiency Appraisal in Freeway Accidents Using Artificial Neural Networks—Case Study." *CICTP 2012* (July 23, 2012). doi:10.1061/9780784412442.269.
- [9] Roque, Carlos, and Mohammad Jalayer. "Improving Roadside Design Policies for Safety Enhancement Using Hazard-Based Duration Modeling." *Accident Analysis & Prevention* 120 (November 2018): 165–173. doi:10.1016/j.aap.2018.08.008.
- [10] Xie, Yuanchang, Kaiguang Zhao, and Nathan Huynh. "Analysis of Driver Injury Severity in Rural Single-Vehicle Crashes." *Accident Analysis & Prevention* 47 (July 2012): 36–44. doi:10.1016/j.aap.2011.12.012.
- [11] Aarts, Letty, and Ingrid van Schagen. "Driving Speed and the Risk of Road Crashes: A Review." *Accident Analysis & Prevention* 38, no. 2 (March 2006): 215–224. doi:10.1016/j.aap.2005.07.004.
- [12] WHO, World Health Organization, "Speed and Road Crashes". PAHO/NMH/18-007, Pan American Health Organization, 2018. Available online: https://www.paho.org/sites/default/files/2018-SpeedRoadCrashes_ENGLISH_FINAL.pdf (accessed on March 2021).
- [13] Wang, Chao, Mohammed Quddus, and Stephen Ison. "A Spatio-Temporal Analysis of the Impact of Congestion on Traffic Safety on Major Roads in the UK." *Transportmetrica A: Transport Science* 9, no. 2 (February 2013): 124–148. doi:10.1080/18128602.2010.538871.
- [14] Retallack, Angus Eugene, and Bertram Ostendorf. "Current Understanding of the Effects of Congestion on Traffic Accidents." *International Journal of Environmental Research and Public Health* 16, no. 18 (September 13, 2019): 3400. doi:10.3390/ijerph16183400.
- [15] Duivenvoorden, Kirsten. "The relationship between traffic volume and road safety on the secondary road network." SWOV Institute for Road Safety and Research (2010). Available online: <https://tarjomefa.com/wp-content/uploads/2017/08/7590-English-TarjomeFa.pdf> (accessed on March 2021).
- [16] Cadar, Rodica Dorina, Melania Rozalia Boitor, and Mara Dumitrescu. "Investigating the Role of Traffic Volumes on the Occurrence of the Accidents on the National Roads: a Case Study in Romania." *Geographia Technica* 12, no. 2 (October 27, 2017): 20–29. doi:10.21163/gt_2017.122.03.

- [17] Vey, Arnold H. "Improvements to Reduce Traffic Accidents." Transactions of the American Society of Civil Engineers 104, no. 1 (January 1939): 474–484. doi:10.1061/taceat.0005186.
- [18] Raff, Morton S. "Interstate highway-accident study." Highway research board bulletin 74 (1953): 18-45.
- [19] PIARC, Road Accident Investigation Guidelines for Road Engineers, World Road Association PIARC Technical Committee, (August, 2007). Available online: https://www.who.int/roadsafety/news/piarc_manual.pdf (accessed on March 2021).
- [20] Wang, Chao, Mohammed Quddus, and Stephen Ison. "A Spatio-Temporal Analysis of the Impact of Congestion on Traffic Safety on Major Roads in the UK." Transportmetrica A: Transport Science 9, no. 2 (February 2013): 124–148. doi:10.1080/18128602.2010.538871.