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RESEARCH ARTICLE Open Access

Improving the Level of Service and Capacity of Shorish Road in Erbil Using HCS7 and HCM2010

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Abstract: The core of highway design, planning, management, traffic control, capacity forecasting, and determining level of service is built on understanding the relationships between speed, flow, and density factors. The classification of urban streets into various street classes and speed-based levels of service categories is well defined in HCM 2010 and is particularly applicable in homogeneous traffic flow conditions. The Kurdistan Region is situated in northern Iraq, with Erbil serving as its capital city. The study aims to acquire speed data using a video camera and evaluate its usefulness in determining the speed ranges of LOS groups applicable to the current situation. Methodology that is used in this research is to apply HCM 2010 method for Shorash street in Erbil city. Also, two methods were utilized that are video photography and moving vehicles method. The speed ranges for urban streets in Erbil city context need to be defined according to demand on the roads because of high demand on this road. clarify is to acquire speed data using a video camera and how useful it is in determining the speed ranges of LOS groups that apply to the current situation. The Level of Service (LOS) obtained using both the video camera technique and HCS7 was the same, LOS = F. The results show, factors including traffic density, speed limits, the frequency of crossings, the existence of bus stops, on-street parking, roadside commercial activity, and pedestrian activity have a significant impact on service levels for main roads connected to 60, 40, 30, 100 m ring road in the city.

Keywords: *Peak-hour Factor (PHF; Capacity and Level of Service (LOS).*

1. Introduction

This document outlines traffic flow theory and simulation models, as well as the capacities of road networks [1]. Capacity is typically defined as the maximum hourly rate at which people or vehicles can reasonably be expected to pass through a specific point or uniform segment of a lane or roadway within a given time frame, considering the prevailing roadway conditions, traffic, and control measures [2]. In addition, the rise in population and economic growth over the past ten years have increased the number of vehicles. The design of road facilities, transportation planning, and traffic control all benefit from studying and understanding the relationships between traffic speed, flow, and density [3]. Ignoring these connections could result in a variety of issues with transportation policy, as well as an increase in traffic and pedestrian delays, major issues for the neighborhood, and an increase in the number of fatal incidents. Therefore, it is necessary to change the geometry and other features of the road conditions [4] the result study in the field. Highway Capacity Software 7 (HCS7) is a traffic analysis software suite that includes various modules implementing the procedures and methodologies specified in the HCM, 6th Edition. HCS7 is designed to analyze several modules and sub-modules, and it is a widely recognized tool that allows for quick and straightforward analysis using simple parameters and inputs. HCS2010 software optimizes the performance of signalized intersections by replace with that the in-cycle time that led to reducing of delay and queue length at signalized

intersections [5,6]. This road is the main road for the city and a high percentage of population use this this so the design of road has some problem to solved it and changing LOS Road. These are some factors related to roads [7]: Number of lanes, The type of facilities and the setting for its development, Lane dimensions [8], The lateral clearances and shoulder widths and Design speed. To develop Develop empirical models for particular areas and analyze the traffic flow characteristics in Erbil City, speed-flow-density relationships are established [9, 10].

2. Aim and Objectives of The Study

This study seeks to identify and evaluate the factors influencing the speed, flow, and density of urban roadways, including aspects like parking and taxi locations and bus stops, pedestrian activity, pavement conditions, and the geometry and width of the carriageways. Additionally, the activities within the city significantly influence traffic flow and are, in turn, affected by it. The project intends to:

1. Researching the relation between various aspects of traffic, including (speed, flow and density).
2. Determining the road's capacity, PHF and LOS using video camera technique, moving vehicle method and using HCS7 software.
3. It helps in determining how well traffic flows and the comfort and convenience experienced by drivers.

3. Methodology

Data that were gathered at a particular site on particular routes in Erbil City were used to conduct this study. First, information was collected about the road's geometric features, such as the number of lanes, lane widths, shoulder widths, and the length of the stretch that we worked on, the second type of data collected pertains to traffic flow in both directions during morning and evening peak hours, which constitutes the majority of the data gathered. This information was obtained through two methods: video recording and monitoring moving vehicles. To capture a sufficient length of road while minimizing the impact of driver behavior changes due to speed variations, data collection was conducted using a video camera positioned in areas with unobstructed views. Each location's data is gathered over the course of three consecutive regular workdays on Monday, Tuesday, and Wednesday. It will be helpful to gather information about any existing street so that it can be used later to redesign or solve a problem with the road. As for the additional approach, which involves moving vehicles some day of the week used for video camera method. The HCS-Multilane method was used for analyzing uninterrupted (segment) flow on arteries highways, based on the HCM. Data required for multilane analysis is traffic data, such as hourly traffic volumes and peak hour factors, number of lanes, grade, vehicle composition and classification, free-flow speed, lateral clearance, median type, and number of access points per km. The output of the analysis includes flow rate, free-flow speed, density and LOS.

3.1 Site Selection

The decision of selecting a study area is based on daily problems in Erbil City. Shorish street is one of the busiest streets in Erbil City specially in peak hours, it connects city center to outer areas of the city. Moreover; drivers who that come from out of the city choose this way because it is acts as a link. Best on the last seven years the average increase of vehicles annually is 9.132% (Traffic Police Directorate of Erbil, 2016 and Census Directorate of Erbil, 2022), this is by all means not a normal incensement. The roads are not designed for all these vehicles, because of these high delays occur and roads face huge deterioration. Studying on this road can help to collect traffic data and then redesign the road by using collected data. This can help improving people’s daily life and reduce delays in this street. Identifying the study area where LOS must be defined is a prerequisite for identifying LOS for the purpose of calculating running and delay time at the end of each stretch, the segment or road on which the LOS segment was selected should be broken into tiny sections. Roads were chosen according to different traffic flow conditions, including factors such as flow intensity (volume, capacity ratio, and

traffic composition) Table 1 and Fig. 1 display the names of the study locations for the selected roads on the map, and Fig. 2 displays the geometric information for the same roads one of the main topics of this study that needs to be concentrated on is population dynamics. They can gain a better understanding of how the community functions and discover a connection to forecast future resource use by analyzing population dynamics. Table 3 illustrates the population and number of automobiles (all types of vehicles) in Erbil. Both numbers have been rising quickly over time. For instance, the population is 2,009,637 in 2015 and increased to2,456,765 in 2021. It can be seen that the population is growing by 2.9% yearly. This means that the number of cars is increasing in a linear manner, as seen in Fig. 3. The implementation of safety system efficiency indicators promotes the improvement of road conditions, the development of the transport system, and social and economic development [11, 12]. Data of two different categories were gathered. First, manual field measurements are made of the road's physical characteristics, such as the number of lanes, lane widths, and segment lengths for each place. Because the shoulder width varies from location to location, an average is determined for calculation needs data shown in Table 2 The second type of data is the main component of data that is gathered using video photography techniques for traffic flow in both directions during morning and evening peak times [8]. To capture an adequate length of road while minimizing any influence on driver behavior that might affect their speed, the operation is carried out Utilizing a video camera positioned in locations with unobstructed views; Geometric data in section of the study area, Traffic counting to show the hourly flow variation and to define the peak and off-peak hours, Flow and speed measurement during peak hours using video camera recording technique, Calculated density by relationship between speed and flow and Input data for analyzing flow, capacity and LOS. Weather and environmental condition affects the people's movement, this is important to be noted while collecting data on roads, the weather condition while we conducted this study was cold and the season was winter, in Kurdistan region and specially in Erbil the temperature decreases in winter.

Table 1: Locations of The Selected Roads Studied.

Section	Location and Name	Direction of Road		Zone Function	Coded Number
		From	To		
A	Shorish Road (Radial Road Conceded to 60m Ring Road)	Mega Mall Road	Shorish Intersection	Commercial	A-B
B		Shorish Intersection	Mega Mall Road		B-A

Table 2: Geometric Data of Selected Roads Studied.

Section	Width of shoulder, (m)	Width of carriage way, (m)	Width of median, (m)	Divided Yes, or No	One way or two ways	Section length, (m)	Total width of carriage way including median width, (m)	Limits of Speed (km/hr)
A-B	6m	14.44	8.6	Yes	Two Way	600	23	60
B-A	6m	14.32						

Table 3: Population and Number of All Types of Vehicles in Erbil City.

Years	Population	Population increased annually, %	Number vehicles	Vehicles increased annually, %
2015	2,009,637	2.557	569813	13.87
2016	2,062,380	2.414	661645	6.202
2017	2,113,391	2.271	705396	8.764
2018	2,162,509	2.176	773161	10.927
2019	2,209,569	3.934	868013	6.158
2020	2,400,100	2.301	900214	9.002
2021	2,456,765	2.301	989278	9.002
2022	2,009,637	2.557	569813	13.87

Figure 1: Geometric data of the Study Area.

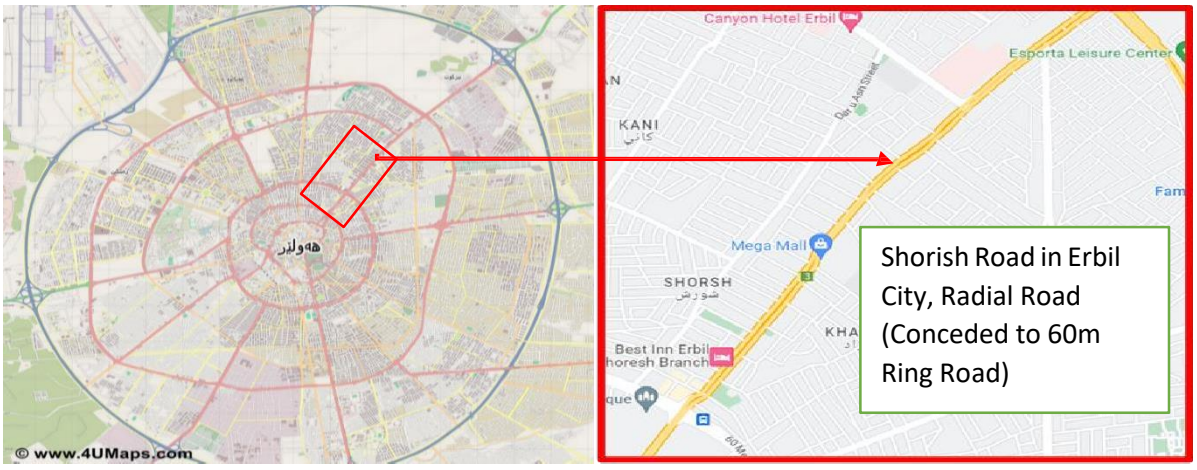

Figure 2: Study Area Location.

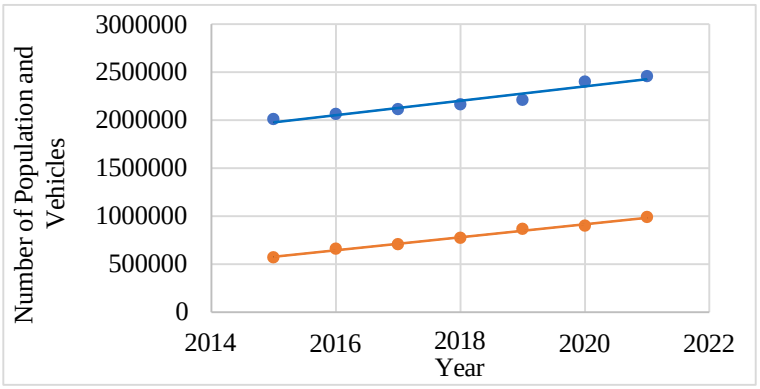

Figure 3: Population and Number of Vehicles Line Chart (Blue = Population and Orang e= Number of Vehicles).

3.2 Methods of Calculation

The most common types of data collected for the purposes of traffic engineering are vehicle Flow and speed data. The following sections will describe how to record this information and what factors are important to keep in mind as the collection takes place. The data on All recordings were made during morning and evening peak hours using a video camera, with the footage stored in the camera's memory. The data was then downloaded from the camera and stored in a suitable format on a laptop for further analysis [13]. Geometric data measurements were taken on-site using tape, and the length was measured by vehicle gauge and checked by tape. All the other data were obtained from the municipality and traffic engineering department of traffic police directorate in Erbil. The traffic data is the basis of all analysis in a traffic impact study and careful consideration should be given to the locations, types of counts and duration of counts. Data collection using video cameras was conducted over three days—Monday, Tuesday, and Wednesday—during 12 continuous hours each day, from 7:00 AM to 7:00 PM. Schools, mosques, hospitals, and shopping centers may influence peak periods due to their unique usage patterns. Therefore, it is important to consider the surrounding land uses before scheduling peak hour counts within a limited timeframe [9]. As for the moving vehicle method, the data are collected manually by four students in field, after selecting a section and finding the distance of the section, two directions are marked, A to B and B to A. three days in middle of the week were selected to collecting the data. Each day for morning and evening peak hours, each time eight runs in each direction [14]. The advantages of using video camera methods include the ability to record A significant number of events occurred during the observation period, along with the ability to differentiate vehicle volumes by lane. However, the Manual Vehicle Method (MVM) offers a lower cost for on-site data collection [15].

(1) Average speed (km/hr) = (D)/(Us)

Where:

Average speed is expressed in kilometers per hour
D: Distance is expressed in kilometers
Us: Average Travel Time is expressed in hours

(2) $$U^s = \frac{\sum f_i}{U_i}$$

Where:

U^s: average speed of traffic.
∑fi: The summation of fi could represent the total flow of traffic
Ui: This likely represents the flow rate or the total number of vehicles counted

Vehicles of different types have different space between them and have different effects on the capacity of highway because of variation in size and performance so the flow is necessary to be converted to Passenger Car Unit (PCU) which is obtained from equation in reference [14] and the flow was computed from equation (4) [15].

(3) PHF = V60/4*V15

Where:

PHF = Peak Hour Factor
V60 = Total hourly volume
V15 = Peak 15-minute volume within the hour
A-B = PHF = 7797 /4*2056 = 0.948
B-A = PHF = 6509/4*1822 = 0.893
Speed and flow were measured simultaneously every 15 minutes.

(4) q = n*60/5 (pc/hr)

Where:

q = Flow, pc/hr
n = Number of passenger car

It is the number of vehicles (N) over a stretch of a roadway (L) estimated point measurement using equation through the relation between speed and flow. The PCU factor is based on the paper published by [16]. Selected Level of Service (LOS) According to (HCM2010 and HCS7): The operational, design, and planning levels of analyses that are frequently carried out by HCM users can be divided into three groups. Operational analyses are HCM applications that are typically focused on the present or future. They are intended to provide information so that decisions can be made regarding the need for rapid, minor improvements that are often inexpensive. On occasion, analysis is performed to evaluate whether a more thorough planning study is necessary. The procedures in this study assess the reduction in travel speed that occurs under less-than-ideal conditions. Under base conditions, a multilane highway operates at its full speed and capacity. These base conditions include favorable weather, clear visibility, and the absence of incidents or accidents. Research on the flow characteristics of multilane highways has established these base conditions to develop flow relationships and speed adjustment factors. The base conditions for multilane highways are as follows:3.6m minimum lane widths: 3.6m the minimum total lateral clearance in the direction of movement is the distance between the edge of the traveled lanes and any impediments in the median and along the edge of the road. (In computations, lateral clearances greater than 1.8m are considered in computations to be equal to 1.8m), The traffic stream is only passenger cars, Along the roadway there is no direct access points, Highway is divided and Free-flow speed (FFS) higher than 100 km/h.

The multilane rural and suburban highways are operated at their highest operational level under these base conditions. The following scenarios that can happen between crossings are not explicitly taken into consideration by the urban street's methodology [4]: Availability or absence of on-street parking, Controlling access or driveway density, Lane changes as traffic flows toward or away from intersections, The effect of intersectional grading, Potential capacity restrictions at intersections (such as a narrow bridge) and Midblock medians and left-turning two-way lanes. The length of time spent traveling is one of the elements taken into account for service quality. Speed and travel time are therefore seen as crucial variables in determining whether the Level of service is upgraded or downgraded [3] A to F grading, is used to more accurately represent the capacity of a roadway. On different days and at different times, the volume of traffic varies. With List of Service, there would traffic service quality on a particular flow rate of traffic. Elements that are used to evaluate LOS are according to HCM: Travel speed and time of travel, Volume to capacity (V/C) ratio, Density (number of vehicles per unit length on highway), Delay (at intersection, signals) and PHF the ratio of the total flow during the entire peak hour to the maximum flow rate observed during any 15-minute interval within that hour. According to the HCM, these factors are detailed in Table 4 for urban roads.

4. Results

In this section, detailed data were collected, examined, and discussed. The speed and volume data, directly obtained from on-site field observations, are thoroughly described and analyzed. Traffic flow densities were calculated using the measured speed and flow. Relationships between speed and density, flow and density, and speed and flow were established. Additionally, other findings, such as traffic

delays, were analyzed and discussed. This section includes a comparison of the traffic flow characteristics recorded during the site studies conducted in this research, such as: Volume characteristics of urban roads, Space mean speed and its statistical parameters for all study sections, Travel speed and travel time for all sections within the study locations, Speed-flow-density relationships for all sections in the study and Determine LOS for urban road.

Table 4: Urban Street LOS by Class (HCM 2010).

Urban Street Class	I	II	III	IIII
Range of FFS	90 to 70 km/h	70 to 55 km/h	55 to 50 km/h	55 to 40 km/h
Typical FFS	80 km/h	65 km/h	55 km/h	45 km/h
LOS	Average Travel Speed km/hr			
A	>72	>59	>50	>41
B	>56-72	>46-59	>39-50	>32-41
C	>40-56	>33-46	>28-39	>23-32
D	>32-40	>26-33	>22-28	>18-23
E	>26-32	>21-26	>17-22	>14-18
F	≤26	≤21	≤17	≤14

Volume Studies: Systematic traffic surveys, traffic studies, and their scientific analysis are crucial for traffic engineering and have several applications in the design of pavements, regulating and controlling traffic, and planning for future road demands. Traffic surveys, also known as traffic censuses, include data on the types of traffic, vehicle weight and size, traffic flow, hourly and daily traffic volume, seasonal and annual fluctuations, as well as the distribution across different regions of the road network and directions at intersections. Fig. 4 indicate Shorish Road's peak hours in the mornings (8-10)am and evenings (3:30-5:30)pm in January and February. Traffic Composition: Passenger cars, pickup trucks, vans, minibuses, buses, trucks and trailers, and motorcycles are among the vehicle types on the chosen road sections and throughout the study period show in Fig. 5. The vehicles types on the studied road stretch are divided into percentages based on the various vehicle kinds listed in [17]. The city's highest value related to passenger cars and lowest value related to vans. Traffic Flow Characteristcs relationships the primary objective of this research is to establish speed-flow-density relationships that can be utilized by engineers and planners for the design, planning, and operation of traffic systems. To develop relationships between speed, flow and density regression analysis was used [19]. Average of Speed, flow and density by two methods are shown in Figures 6,7 and 8. The main relationship models are; speed-density, flow-density, and speed-flow. The reliability of the model is assessed using the coefficient of determination P-value. Subsequently, the level of service (LOS) for each direction of the road is determined to aid in selecting optimal transportation planning for the urban area. Speed-flow relationships are derived from the general equation $q=k\cdot u$. Linear models were developed, and data were gathered to determine which model best fits and accurately represents the observed data. Based on data collected in field with using moving vehicle method, there are three relationships that plotted and are represented below for each time segment in selected area. The P-value ranges from 0 to 1, where a value of 0 indicates that the independent variable does not account for any changes in the dependent variable. Conversely, a value of 1 signifies that the independent variable perfectly explains the variation in the dependent variable. Typically, it is expressed in the form of a percentage for easy reference. Relationship of graphs shows different results by using linear equations and regression. For flow-density it shows a good relationship because the value is near to one which is good. But for Speed-density and speed-flow relationship is not near to 1 and it is mostly less than 0.5, this is not showing a good relationship. Just one sample of data collected in site mention in Fig. 4 for section A-B and B-A at morning and evening work. Which model is the best fit and best represents is the observed

data. All models have been tested, and combination models have also been developed and analyzed. The parameters for the best-fit models for each section are presented in Table 5, based on data collected using both the video camera and MVM method. The resulting models are illustrated in Fig. 10, which depicts the models derived from the MVM method and data gathered through the video camera method. Another measure of reliability of the relationships is P-value. It is less than 0.000 which indicates that it is statistically significant for both methods and linear model, rejecting the null hypothesis in favor of the alternative hypothesis (the relation between two variables is strong and two variables are related to the population side in study).

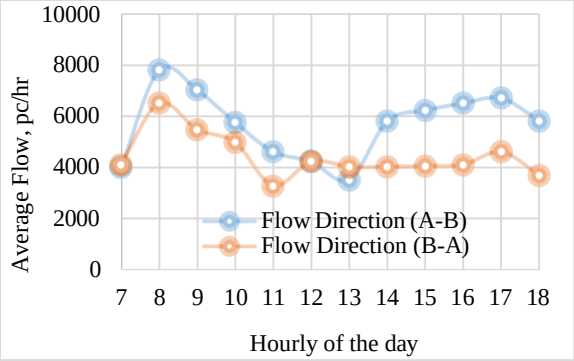

Figure 4: Hourly Flow Duration from 12 hours.

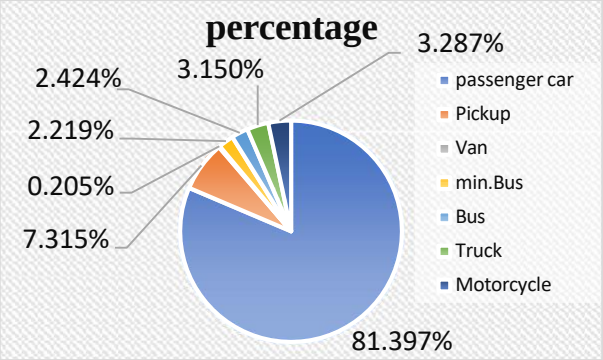

Figure 5: Average Percentage of Vehicles Composition in the Study Area.

The calibration results from linear model, summarized in Fig. 9 for the data collected by MVM and Figure 10 for video camera, then the data are compared in terms of free flow speed (Uf), capacity (qm), optimum density (km), optimum speed (Um) and the goodness of fit (P-value). The relationship uses for calculated capacity of each direction. Evaluation of Traffic flow parameters: Urban Street LOS is determined by the average travel speed of through vehicles, either for a specific segment or the entire street being evaluated. Travel speed serves as the primary service metric for urban streets. The average travel speed is calculated by combining the running times along the street and the control delay experienced by through movements at signalized intersections.

Table 5: Best Fit and Worse Cause Between Each Relationship.

Relationship	P-value	P-value
Flow-Density	0.996	0.015
Speed-Density	0.6848	0.0065
Speed-Flow	0.448	0.0002

According to multi-lane of the highway some point of road are not checked such as 3.6m minimum lane widths, only passenger cars in the traffic stream and Free-flow speed (FFS) higher than 100 km/h. So, using urban road in the city is according to HCM. LOS of Shorish road for both sections are mentioned in Table 8. At LOS D, traffic congestion significantly limits the ability to maneuver. As traffic volume increases, travel speed decreases. Even small disruptions can cause long queues to form, leading to a further decline in service quality. Disruptions are not easily dissipated, often leading to the formation of queues and a decline in service to LOS F. On most multilane highways with free-flow speeds (FFS) between 70 and 100 km/h, the mean speeds of passenger cars at capacity typically range from 68 to 88 km/h, though these speeds can vary significantly and are difficult to predict. For multilane highways, the upper limit for low volume is 1,400 passenger cars per hour per lane (pc/h/ln). For section direction to Shorish Intersection is equal to 2056 (pc/h/ln) and 1822 (pc/h/ln) for direction to mega mall more than standard value. The ratio of hourly demand to four times the peak 15-minute demand generally results in a PHF range of 0.75 to 0.95, with higher values typically observed as

demand nears the facility's capacity. In the absence of local data, a default value of 0.92 can be applied for urban areas; however, in one section, this value is specifically 0.893. According to HCM for section (B-A) and (A-B) some LOS equal to F. In urban areas generally, PHFs ranges between 0.80 and 0.98. PHFs over 0.95 are often indicative of high traffic volumes, sometimes with capacity constraints on flow during the peak hour. PHFs less than 0.8 occur in locations with highly peaked demand such as schools, university, time of start or end offices, factories with shift changes and venues with scheduled 60 events [4]. The PHFs in this study ranges between 0.89 and 0.95. The detailed characteristics of traffic on study road locations are shown in Table 6,7, and 8. The same result of LOS equals to F by using HCS7 software as shown in Table 9 because same factor using in HCS7 but don't use in HCM.

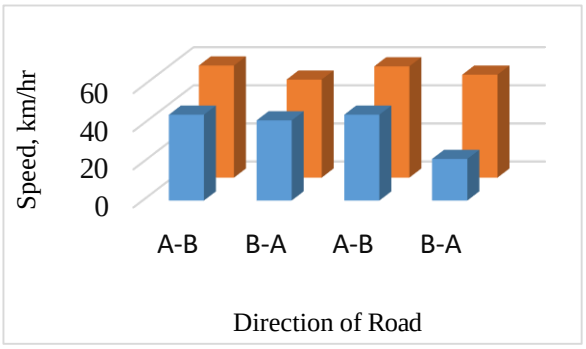

Figure 6: The Average Flow by Video Camera Blue And MVM Orang.

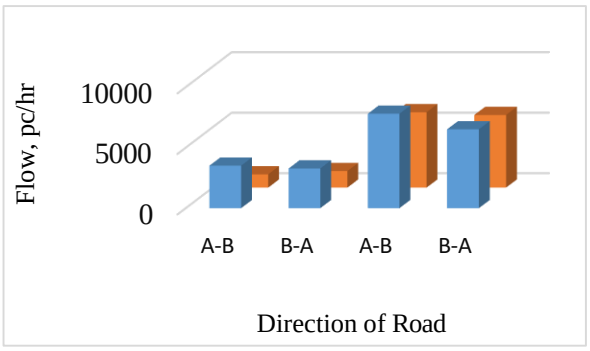

Figure 7: The Average Density by Video Camera Blue and MVM Orang.

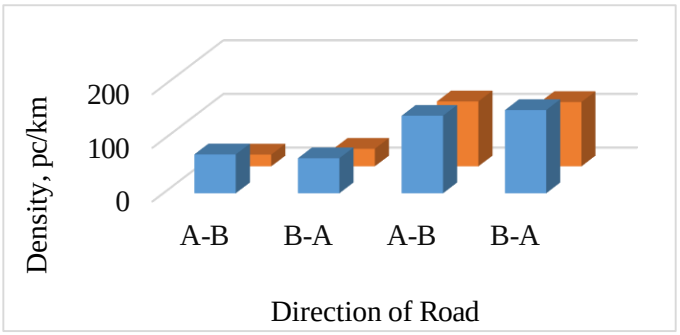

Figure 8: The Average Density by Video Camera Blue and MVM Orang.

Table 6: The Average Capacity Based on Speed-Density Model.

Section	Capacity
A-B	5373
B-A	3199

Table 7: The PHF by Video Camera

Section	PHF
A-B	0.948
B-A	0.893

Table 8: Urban Street LOS and Class by Urban Road (HCM)

Section	Average Travel Speed, Km/hr	Average Free Flow Speed, Km/hr	Class	LOS	Capacity	PHF	LOS
A-B	45	77	I	D	5373	0.948	F
B-A	35	65	II	D	3199	0.893	F

5. Discussion

According to the findings of this study and the analysis of the data gathered in Shorish Street, a number of factors contributed to this issue. The measured ranges of the fundamental traffic flow characteristics of flow, density, and speed are as follows:

1. Although the speed limit is 60 km/h, a significant speed overrun causes congestion and traffic jams since turning at intersections becomes more difficult at higher speeds. The measured ranges of the fundamental traffic flow characteristics of flow, density, and speed are as shown in Fig. 9,10 and 11 and Table 10 and 11.
2. The Flow-density relationships have the best match model, but there are poor relationships between Speed-Density and Speed-Flow.
3. The PHF factor between 0.89 and 0.95 indicates a significant demand on the road because it is the primary route into the city.
4. There are typically two methods for measuring flow and speed: the first uses a video camera, which takes a lot of time and has some placement and electricity issues. Despite these issues, the field study was able to obtain the precise data because the entire data set was saved and could be combined at home for analysis. The effective, useful, and economical second method by MVM.
5. The Level of Service (LOS) results for both methods are the same for multilane roads, but differ when calculated for urban roads across various categories, as shown in Table 12.

Table 9: Urban Street LOS And Class by Multi-Lane (HCS7).

Section	Data Observed	Data Observed
A-B	Demand Volume, V	7528 veh/h
	Peak Hour Factor, PHF	0.948
	Flow rate, v_p	2779 pc/h/ln

	Capacity, C	1956 pc/h/ln
	Base Free-Flow Speed, BFFS	77.0 km/h
	Number of Directional Lanes,	3
	Terrain Type	Level
	LOS	F
B-A	Demand Volume, V	7528 veh/h
	Peak Hour Factor, PHF	0.893
	Flow rate, v_p	2779 pc/h/ln
	Capacity, C	2204 pc/h/ln
	Base Free-Flow Speed, BFFS	100.0 km/h
	Number of Directional Lanes,	3
	Terrain Type	Level
	LOS	F

Table 10: Average Speed, Flow and Density by Video Camera.

Section	Speed, km/hr	Flow, pc/hr	Density, pc/km
A-B	45- 56.8	3515-7802	72.47- 144.48
B-A	42- 51.42	3281- 6515	65.35- 155.11

Table 11: Average Speed, Flow and Density by MVM.

Section	Speed, km/hr	Flow, pc/hr	Density, pc/km
A-B	45-58.37	1096-6225	21.95-121.06
B-A	21.83-54	1366-6000	32.8-119.9

Table 12: Level of Service (LOS) for Various Categories By HCM and HCS7

Section	Multilane (HCM)	Urban Road (HCM) LOS	HCS7
A-B	F	D	F
B-A	F	D	F

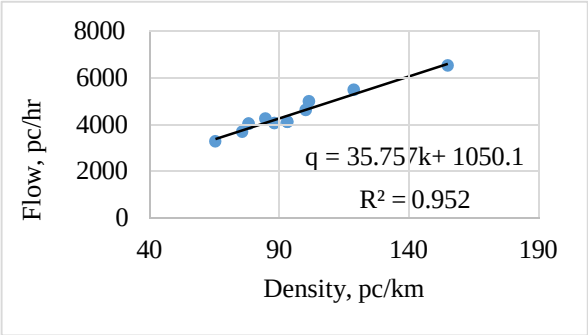

Figure 9: Relationships between Flow-density using Video Camera.

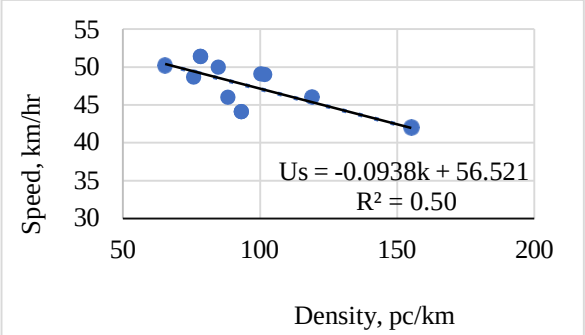

Figure 10: Relationships between Speed-Density using Video Camera.

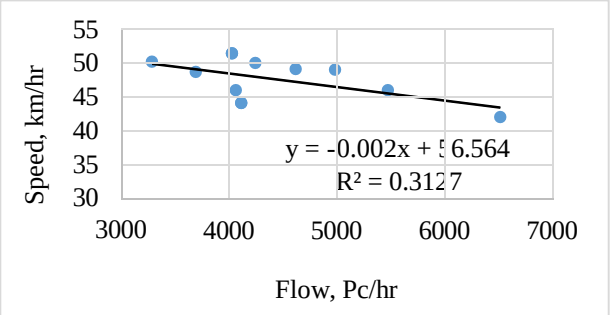

Figure 11: Relationships between Speed-Flow using Video Camera

6. Conclusion and Recommendation

6.1 Conclusion

This outcome demonstrates that the type of road is not particularly terrible, but other factors affect it, such as:

1. The flow and speed of the road are significantly influenced by the presence of four U-turns and a traffic intersection located in the middle of the street.
2. The street has a signalized intersection at one end and in the middle, which causes a heavy flow of traffic as the light turns green. This heavy flow makes turning extremely difficult because the speed of the traffic will increase once the light turns green, especially during rush hours when people are rushing to get to work.
3. Due to on-street parking, which is caused by the abundance of restaurants and shopping centers combined with the lack of off-street parking, the flow and congestion on the road will be reduced and one lane, sometimes more, will be blocked off to traffic.
4. This route connects the city center to the outside of the city, making it more accessible to cars traveling within the city. This additional traffic necessitates improvements to the road's accessibility, mobility, and kind of driving.
5. An urban metropolis's major issue is the quantity of passenger cars in the city. Public transportation is more readily available and accessible in metropolitan regions due to the density of population and the proximity of infrastructure compared to rural locations.
6. The lane widths often 6m offer sufficient safety in metropolitan areas while discouraging speeding. Cities have the option of using 3.6-meter lanes on authorized bus and truck routes (one 3.6meter lane per direction) or next to lanes traveling in the other direction.

6.2 Recommendation

All the work, findings, and recommendations are summarized as follows. The usage of a large number of private vehicles by road users as a result of ineffective public transportation is the most startling finding shown in Fig. 12 Redesign Road Section After Data Analysis.

1. In order to manage these spots, the effects of parked cars on the sides of the road must be studied, as well as turning points to reduce delay.
2. The section's median and shoulder widths are kept to a minimum so that one lane can be used for parking and three lanes may be used for traffic.
3. Erbil City must take into account other networks using the video capturing approach in order to create traffic flow models for urban highways.
4. Creating a suitable design for road marking.
   Marking design: long lines are positioned on the surface of the road in the direction of traffic flow. Their purpose is to warn the driver where they should be positioned on the roadway. Necessary markings are as below: Traffic lane marking, Border or edge line, Warning lines and Bus lane markin.

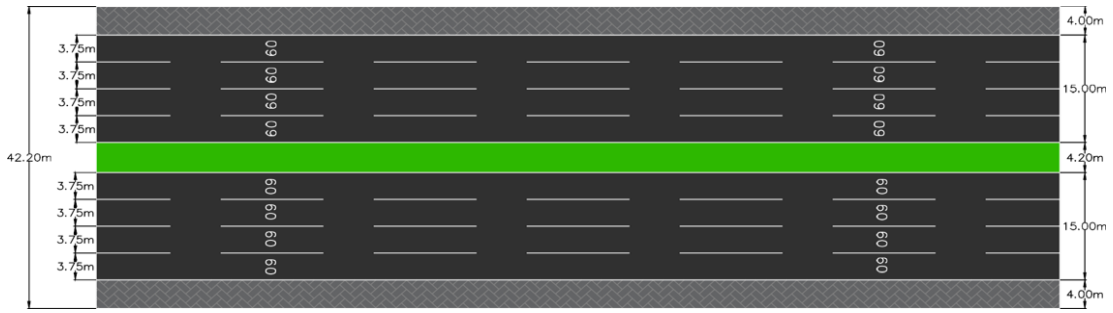

Figure 12: Redesign Road Section After Data Analysis

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