Çankaya University Journal of Science and Engineering
Volume 10 (2013), No 2, 203–218.

# Speed Policies and Guidelines For The Urban Roadway Network in Al-Ramadi City

Mahdi I. Thamer Alkubaisi

*Renewable Energy Research*
*Center-University of Anbar - Iraq.*
*e–mail: basaer_b@yahoo.com*

**Abstract.** This paper represents a Free-flow speed (FFS) parameter that is being used extensively for capacity and level-of-service analysis of various types of highway facilities. As a first effort in the trial of developing local highway standards and guidance for Ramadi city, this study collects and analyzes FFS data at eight roadways in Ramadi city. The objectives of this study are to develop models for estimating average FFS and to set posted speed limit designations. The obtained models reflect the most important variables that govern the FFS,which includevehicle type, speed limit, and shoulder type. A regression model was also developed to predict the relationship between the average running speed (ARS) and the traffic volume. The proposed value of a posted speed limit wasfound to be 80km/h, while the recommended design speed for the Al-Ramadi network is 90km/h.

**Keywords.** Free-flow speed, speed limit, design speed, guidelines.

## 1.1. Introduction

Speed is a fundamental concept in transportation engineering. FFS is the term used to describe the average speed that a driver would travel if there were no congestion or other adverse conditions (such as bad weather). The prediction of speed is fundamental in design, planning, operation and layout of road sections. Factorsthat influence FFS are:

1. high way geometry
2. the driver
3. the vehicle
4. the environment, and
5. traffic operations and control.

Speed limits, set by the legislative bodies of governments, may define maximum, minimum or no speed limit and are normally indicated using a traffic sign. They are usually set in an attempt to cap road traffic speed to improve road traffic safety and to reduce the environmental impact of road traffic such as vehicle noise, vibration, and emissions.

This research represents a first effort in the trial of developing local highway standards and guidance for Ramadi city. The study collects and analyzes FFS data at eight road-

ISSN 1309 – 6788 

ways in Ramadi city. The objectives of this study are to develop models for estimating the average FFS and to set posted speed limit designations.

The values from this study suggest that the average $85^{th}$ FFS for all studied roadways is (88.75 km/h) while the average running speed for the case of free flow travelling is (77.7 km/h). The proposed value of the speed limit ranged between 70 km/hand 80 km/h depending on legislative authorized persons and the change in the traffic conditions.

## 2. Problem Statement

A roadway design results in a more suitable relationship between the desired operating speed and the posted speed limit. This is to provide geometric roadway designs that achieve the purpose of the roadway. Such an approach produces conditions of geometry-that should result in operating speeds that are consistent with driver expectations with the function of the roadway. With no regulation or policies guiding the behavior of traffic within Al-Ramadi City, there is an acceptable campaign to construct a highway network. It is there fore necessary to find a relationship between design speed, operating speed, and posted speed limits as a first step in developing guidelines and design policies to govern the behavior of traffic.

## 3. Research Objectives

The objectives of the current work are to provide acceptable standards and guidance for behavior of traffic in Al-Ramadi City. The standards and guidance focus on developing models to predict the FF Sand to set the posted speed limit designation. The obtained models will reflect the most important variables that govern the FFS.
To accomplish these objectives, the following steps were considered to be important:

- Review current practices to determine how speed is used as a means of control and how speed-related terms are defined.
- Collect data needed to develop the recommended procedure(s).
- Develop a set of recommended design guidelines for future applications in the city to develop and enhance efficiency of the network.

## 4. Related Previous Studies and Definitions

In order to develop roadway sections that are consistent in design, there is a need for design speed, operating speed and posted speed limits to be reasonably similar. This leads to the ability to create safe and consistent speed environments that conform to driver expectation [1]. The current design process is inconsistent because it uses the design speed of the most restrictive geometric element for the design of roadways.

MD. Deardoff, et. al. [2] examined data of ten sites by highway type. Each site had a unique posted speed limit sign ranging from 20 mph (30 km/h) to 75 mph (120km/h). Goodness-of-fit test results revealed that average free-flow speeds are strongly associated with posted speed limits with correlation coefficients of +0.99, +1.00, and +1.00 for urban roadways, multilane highways, and freeways, respectively.

Figueroa and Tarko [3] studied the effect of various roadway and roadside design features on operating speeds on four-lane roadways in Indiana. A regression model was predicted to estimate operating speed. The model showed that increasing the posted speed limit resulted in higher operating speeds. The model also showed that the operating speeds are higher in rural areas.

Fitzpatrick et al. [4] explored speed relationships and agency practices related to speed. Operating speeds at 78 sites in Arkansas, Missouri, Tennessee, Oregon, Massachusetts and Texas were researched. The posted speed limit was found to be a statistically significant predictor of the 85th percentile operating speed on urban-suburban arterials. The estimated models had R2=0.90. The coefficient of the posted speed limit was +0.98, which indicates a positive correlation with the 85$^{th}$ percentile speed.

The Kentucky transportation center [1], conducted research to examine the relationship between design speeds, operating speeds and speed limits in order to address safety and operational concerns regarding the presence of disparities between these speed metrics. The general conclusion for 2-lane highways is that the operating speed differs from the design speed indicating no agreement between them. For the 4-lane highways there is agreement between operating and design speeds indicating the absence of any differences. The relationship between operating speeds and posted speed limits showed that for all roadways these two speed metrics differed and the posted speed limit fell below the 85$^{th}$ operating speed.

In the 2010 Highway Capacity Manual [5] FFS can be determined by deriving it from a speed study involving the existing facility or on a comparable facility if the facility is in the planning stage.

The most often used operating speed parameter is the observed 85th-percentile operating speed. Operating speed-related measures are a result of the design process and may exceed the design speed for a roadway [6]. As a 'rule of thumb' many researchers obtain FFS by adding 5 mp/h (10 km/h) above the posted speed limit.

By looking at the synthesis of the evolution of speed definitions and the latest information on various speed designations, inconsistencies between the definitions and their applications are identified. Hereunder, we briefly define various speed designations based on recent and updated sources and references.

**4.1 Design Speed.** The AASHTO Green Book [7] and MUTCD [8] define the design speed as a selected speed used to determine the various geometric design features of the roadway. The selected design speed is deemed to be a logical one with respect to the anticipated operating speed, topography, the adjacent land use, and the functional classification of the highway. Moreover, AASHTO recommends that the selected design speed ought to conform with the travel desires and habits of the majority of drivers.

**4.2 Operating Speed.** The term *operating speed* is a general term, typically used to describe the actual speed of a vehicle group passing section of a roadway. The AASHTO [7] definition of the operating speed is “the speed at which drivers are observed operating their vehicles during free flow conditions. The $85^{th}$ percentile of the distribution of observed speeds is the most frequently used measure of the operating speed associated with a particular location or geometric feature”. MUTCD [8] defines the operating speed asa speed at which a typical vehicle or the overall traffic operates. An operating speed might be defined with speed values such as the average, pace, or $85^{th}$-percentile speeds.

**4.3. Speed Limit.** Speed limits may define maximum, minimum or no speed limit and are normally indicated using a traffic sign. The factors used in establishing speed limits are: [7]

1. the $85^{th}$ percentile speed;
2. roadway geometry.
3. accident experience; and
4. political pressure.

## 5. Data collection, processing, and analysis.

Eight roadways in Al-Ramadi City: Ceramic Roadway, Ceramic to Huz Bridge Roadway, $60^{th}$ (southern circular) Roadway, $17^{th}$ roadway, Court Roadway, Eastern entry Roadway with two sections and Traffic directorate Roadway were selected for data collection. All of these are divided roads with a raised median within Al-Ramadi City. Their definitions, locations and geometric properties are shown in Table 1. The traffic data were collected in dry weather at a temperature of approximately 38°C and during off-peak periods, from

4:00–6:00 pm every weekday. The collection of data during off-peak times represents free flow vehicle conditions. The traffic flow was composed of passenger cars, pickups, minibuses, trucks, and motorcycles. It is worth noting that motorcycles have recently become a new traffic type in the City.

TABLE 1. Geometric features of the selected study roadways.

| Name | Terr. -ain | Alignm- -ent | Divi- ded | Median type | Lane no. | Should- er type | Pav. width | Pav. type | Adjacent area |
|---|---|---|---|---|---|---|---|---|---|
| 17th | Level | Straight | Yes | Raised | 3 | Raised | 7.2 m | Good | Buildings are close to roadway |
| 60th | Level | Straight | Yes | Raised | 3 | Raised | 14 m | Good | Collector roads, from both sides |
| Cera mic | Level | Straight | Yes | Raised | 3 | Raised | 10 m | Good | Vacant |
| Court | Level | Straight | Yes | Raised | 3 | Raised | 7.2 m | Good | Vacant |
| Hooz | Level | Straight | Yes | Raised | 3 | Raised | 7.2 m | Good | Vacant |
| traffic | Level | Straight | Yes | Raised | 3 | earth | 7.2 m | Good | Vacant |
| Sec1 East entry | Level | Curve | Yes | Raised | 2 | Earth | 7.5 m | Medium | Vacant |
| Sec2 West entry | Level | Straight | Yes | Raised | 2 | earth | 7.5 m | Medium | Vacant |

The video recording technique was chosen in order to collect data. This technique saves time and allows for a large number of events to be recorded at one time and any incident that may occur during the recording session which may result in abnormalities in the observed data can be taken into account. To obtain an accurate recording for proper calculation, a vantage point was chosen for each section of every roadway to set the video camera. In reality, determining the location of such points proved to be more difficult than expected. Nonetheless, data were collected in sessions each of one hour duration. The recorded data were further reduced into sessions of 30 minutes. This duration selection is considered sufficient to provide statistically meaningful samples and to ensure that no large fluctuations occur in the traffic flow. Collected data were then abstracted and grouped to be clear for the next step to complete the research objectives. Table 2 represents the collected and abstracted traffic flow data. Figure 1 demonstrates graphically the traffic flow composition for each selected road way at the study site.

TABLE 2. Roadways Traffic Flow Results.

| Roadway name | Traffic vol., v/h | Pc% | Minibus% | Pickup% | Truck% | Motorcycle% |
|---|---|---|---|---|---|---|
| $17^{th}$ | 800 | 78 | 3 | 8.8 | 1 | 9.2 |
| $60^{th}$ | 270 | 84.7 | 1.5 | 8.9 | 2.3 | 2.6 |
| Ceramic | 450 | 74.8 | 2.1 | 8.3 | 6 | 8.8 |
| Court | 650 | 82.6 | 1.6 | 8.1 | 3.3 | 4.4 |
| Hooz | 350 | 71.7 | 4.3 | 6 | 3.7 | 14.3 |
| Traffic | 845 | 83.8 | 2.6 | 7.2 | 4.9 | 1.5 |
| East entry, sec1 | 1035 | 76.6 | 3 | 6.4 | 13 | 1 |
| East entry, sec2 | 1000 | 78 | 3.2 | 6.1 | 11.5 | 1.2 |

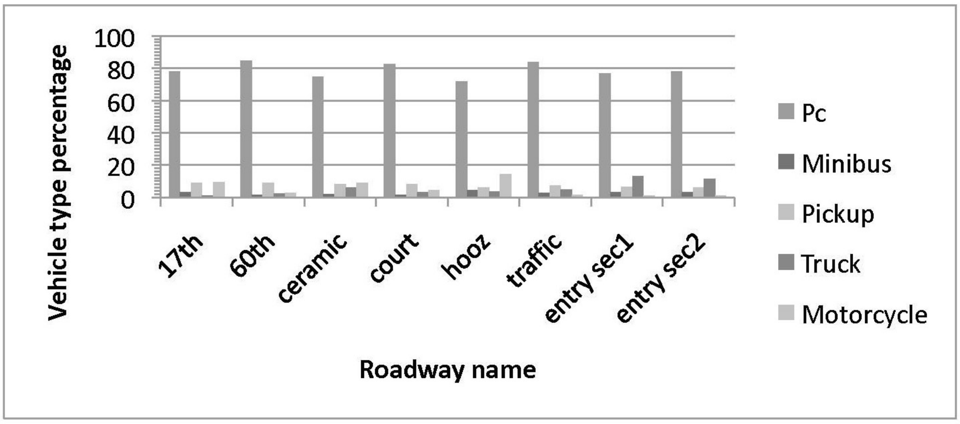


FIGURE 1. Graphical representation of traffic flow composition.

To calculate the mean FFS of passenger car vehicles, the speeds of traffic entities were determined by the time required to travel a known distance (trap length). In this study, the trap length was measured as the distance between two consecutive electric poles or solid lines posted on the pavement of the segment prior to the video recording process. The trap length measured 60 meters. The time required to travel a given distance was determined by recording the entry and exit time of that length. The speed was then obtained from the division of the trap length by the travel time for each vehicle. The values obtained were abstracted foruse in determining the speed characteristics of the total number of vehicles traveling on the study site. To analyze these data, a statistical method is required. The most commonly used method is the frequency distribution table. The selected class interval was set at10 km/h. The data is presented graphically in the form of histograms for all roadways as cumulative frequency distribution curves shown in figures 2 and 3 respectively. Table 3 indicates speed results.

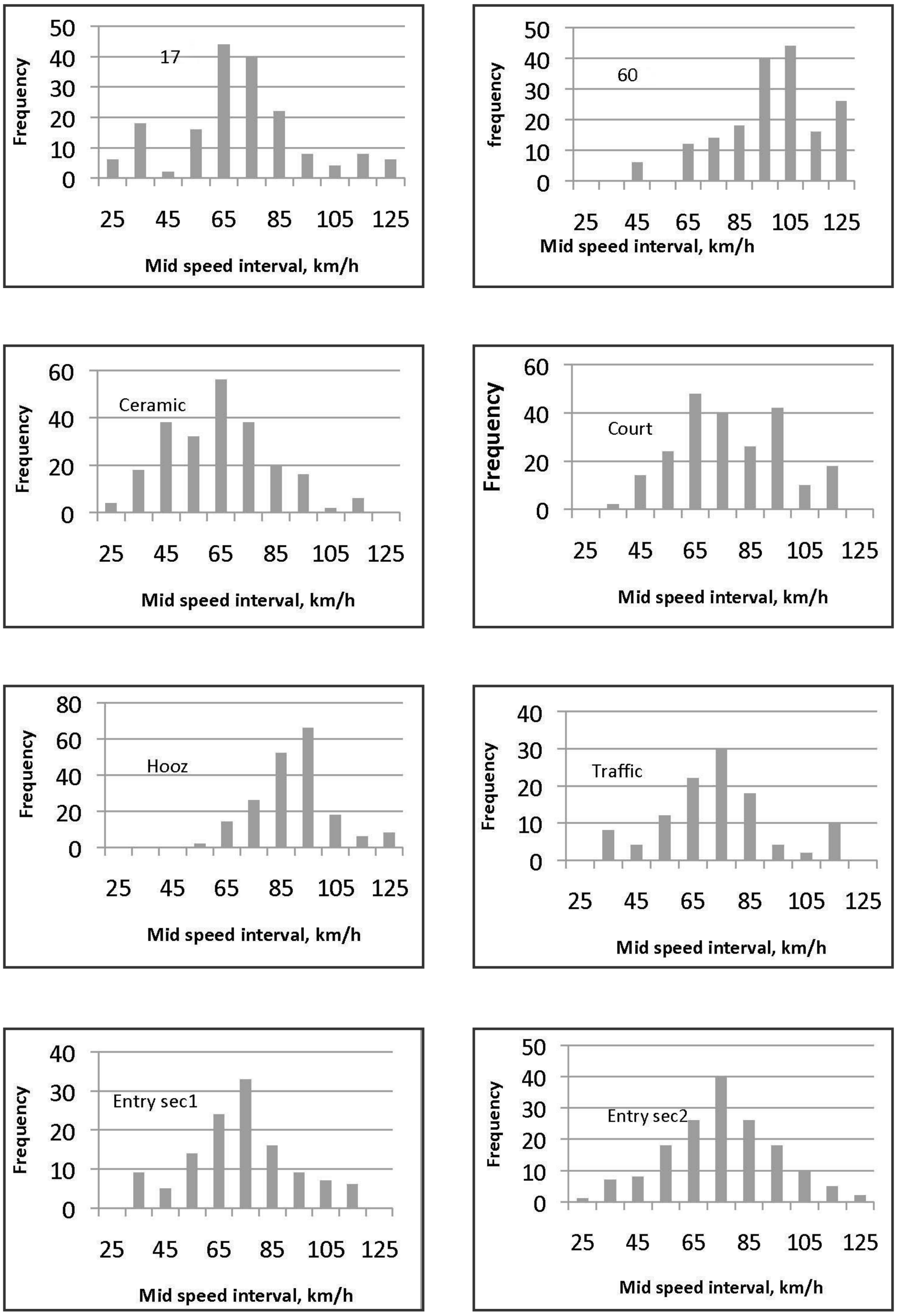


FIGURE 2. Speed frequency histogram.

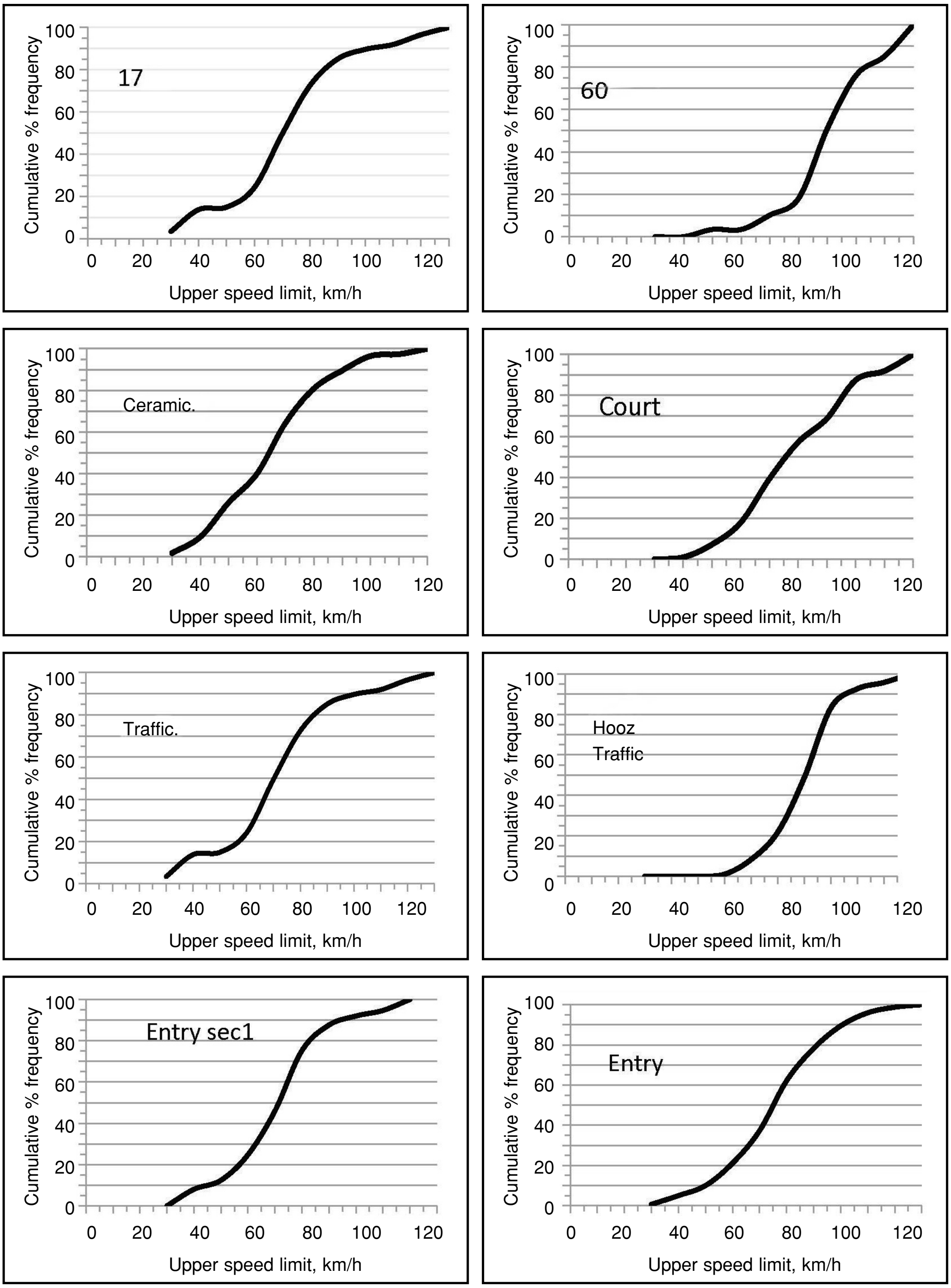


FIGURE 3. Speed cumulative percentage frequency

TABLE 3. Speed statistics.

| Roadway | Speed at free flow traveling, km/h | | | | |
|---|---|---|---|---|---|
| | Running speed | | | | 85th% speed |
| | Av. | Max. | Min. | Std | |
| 17th | 70.9 | 120 | 26.7 | 22.8 | 85 |
| 60th | 97.4 | 127 | 40.7 | 19.4 | 105 |
| Ceramic | 64.4 | 113.7 | 24.2 | 19.3 | 80 |
| Court | 77.9 | 114 | 37.9 | 19.5 | 90 |
| Hooz | 89.8 | 120 | 56.8 | 14 | 96 |
| Traffic | 73.36 | 114 | 35.4 | 20.4 | 86 |
| Entry sec1 | 73 | 124 | 58 | 19.86 | 83 |
| Entry sec2 | 75 | 120 | 55 | 20.23 | 85 |

The corresponding 85$^{th}$ FFS values for the selected roadways are shown graphically in figure 4.

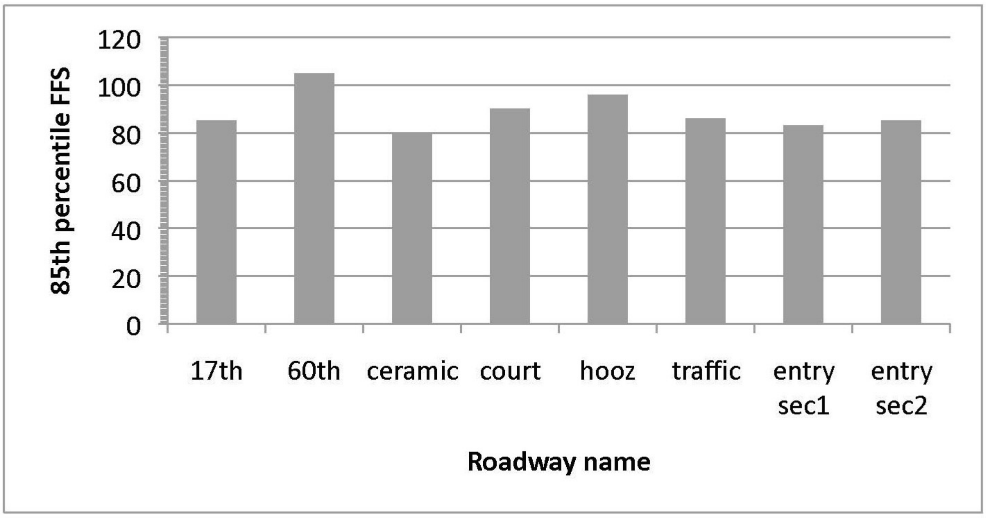


FIGURE 4. Corresponding 85$^{th}$ FFS

# 6. Factors Affecting FFS

The purpose of this section is to study the influencing parameters that affect the FFS. As can be observed from the analysis of the collected data, the main factors affecting the FFS are:

**6.1. Traffic features factor.** The traffic factors which affect the FFS are divided into traffic volume and traffic composition (percentage of heavy vehicles, trucks).
To understand the effect of traffic stream characteristics separately on FFS, it is essential to choose only the roadways with the same geometric features.

Effect of traffic volume: Traffic volumes for each studied roadway were plotted against the corresponding 85$^{th}$ percentile of FFS. Figure 5 indicates this relationship where a regression technique was utilized to fit the data. A good correlation was found and a clear linear effect of the traffic volume was found as given by equation (1)

Y = 105.9 – 0.04*X…………..(1) R2 = 0.958

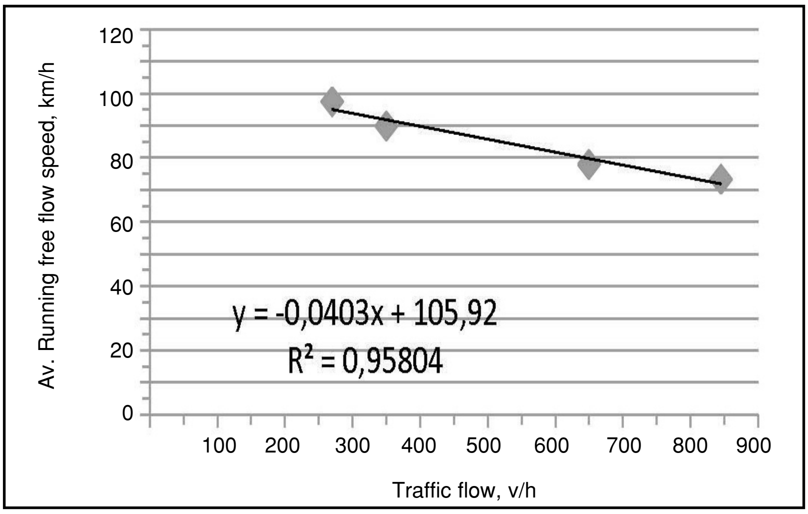


FIGURE 5. Effect of traffic volume on FFS.

Effect of heavy vehicles (Trucks %): The effect of the percentage of trucks on FFS of the stream is shown in figure 7. 1% or less of the data was disregarded due to its unpredicted influence on speed. The relationship is expressed by a linear regression given in equation (2);

Y = 113.9 – 8.261*X…………(2) R2 = 0.819

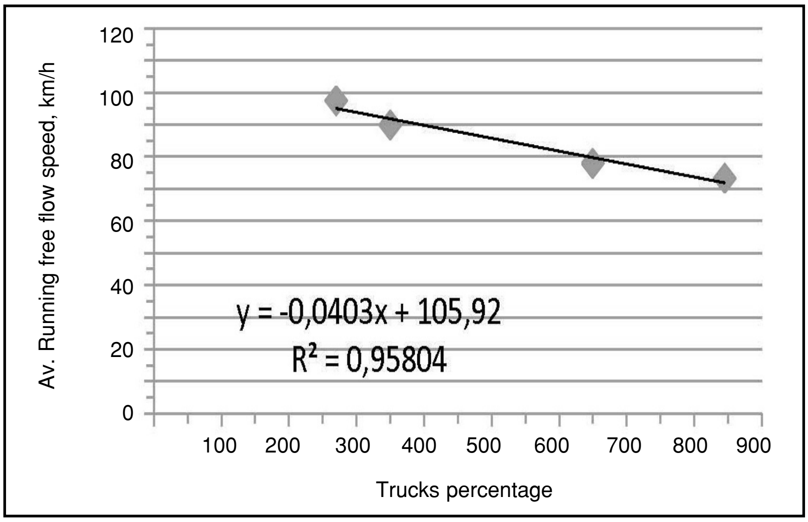


FIGURE 6. Effect of trucks percentage on FFS.

**6.2. Geometric factor.** The selected roadways in this study were located inside Al-Ramadi City. The majority of city network roadways have similar geometric features. They are divided roadways with raised medians of similar width. Pavements may be considered to be in good condition for all roadways due to most having been recently constructed and the remainder having been reconstructed. The only clear geometric differences are the distance of adjacent buildings to the roadways and the shoulder types (five selected roadways have paved and raised shoulders, while others have earth shoulders). The effect of adjacent buildings cannot be studied because there is only one roadway in the study area with adjacent building snear by. The effect of shoulder type is studied below:

The data for roadways with raised and paved shoulders and those with earth shoulder-swere plotted against their corresponding speed values. Figures 7 and 8 indicate results showing linear relationships. They are represented by equations (3) and (4) below for the raised and paved shoulders and for the earth shoulders respectively. Figure 8 demonstrates the underestimated FFS values for roadways which have earth shoulders. This implies that the type of shoulder significantly influences operating speed.

Y = 108.3 -0.047*X…………..(3) R2 = 0.982

Y = 78.74 – 0.005*X……..….(4) R2 = 0.82

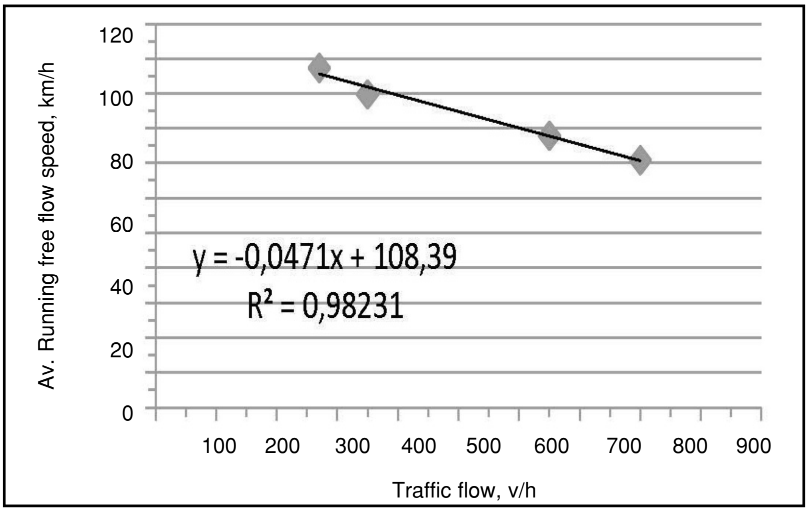


FIGURE 7. Effect of raised shoulder type on FFS.

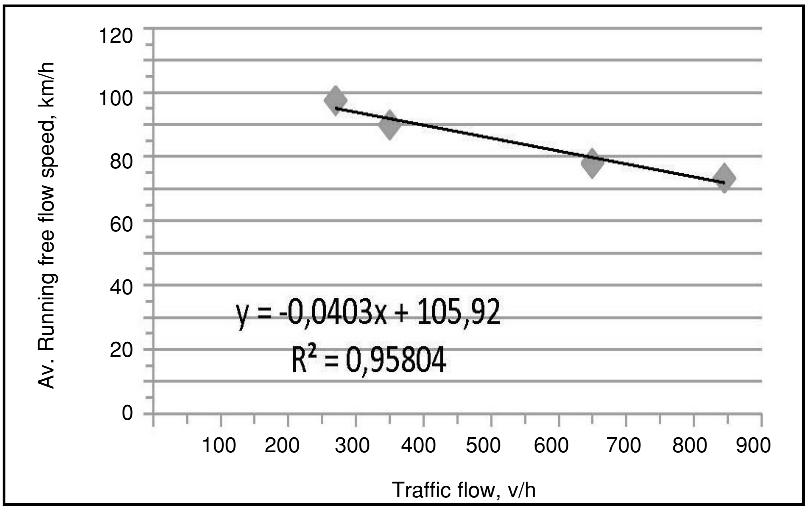


FIGURE 8. Effect of earth shoulder type on FFS.

## 7. Determination of FFS Traffic Flow Relationships

The general form of the above predicted equations for linear regression analysis is as below:

$Y = a+bX$

Where,

$a$ = the operating free flowing condition speed of vehicles

$Y$ = constant

$b$ = coefficient of, and

$X$ = traffic flow.

The predicted equations are listed in Table 4. The first two equations may be represented by one general equation as their constants and are approximately equal in value.

TABLE 4. Predicted Equations.

| Relationship type | Predicted equation |
|---|---|
| Running speed- flow | Y = 105.92 – 0.04*X |
| Running speed-flow with raised shoulder | Y = 108.39 -0.047*X |
| Running speed-flow with earth shoulder | Y = 78.74 – 0.0058*X |
| Running speed-trucks% | Y = 113.95 – 8.26*X |

The general equation which represents the final predicted equation that will be adopted has the following form,

$$Y = 107.15 – 0.044*X \quad (5)$$

According to the definitions above, the general form of the equation is:

$$ARS = 107.15 – 0.044*q \quad (6)$$

where:

ARS = average running speed at free flow condition, km/h, and
q = traffic volume, v/h.

## 8. Posted Speed Limit Designation

*Global standards*

The methods used to set speed limits have been reviewed by several authors. A review was conducted by Institute of Transportation Engineers (ITE) Technical Committee with the following findings [9].

The $85^{th}$ percentile speed is the predominant factor used in setting speed limits.

The top three factors used to establish speed zones other than $85^{th}$ percentile speed were: roadway geometry, accident experience, and political pressure.

Most jurisdictions allow deviations from the $85^{th}$ percentile speed, with most being between 5 and 10 mph (8.1 and 16.1 km/h).

*MUTCD guidelines*

The speed limits shown shall be in multiples of 10 km/h (5 mph).

When a speed limit is to be posted, it should be the 85$^{th}$ percentile speed of free-flowing traffic, rounded up to the nearest 10 km/h (5 mph) increment.

Other factors that may be considered when establishing speed limits are the following:

- Road characteristics, shoulder condition, grade, alignment, and sight distance;
- Pace speed;
- Roadside development and environment;
- Parking practices and pedestrian activity; and
- Reported crash experience for a minimum 12-month period.

## 9. Results, Discussion and Conclusions

The obtained values from this study explain that the average 85$^{th}$ FFS for all studied roadways is (88.75 km/h) while the average running speed for the case of free flow travelling is (77.7 km/h). According to the above guidance and standards, the posted speed limit is either equal to the 85$^{th}$ percentile FFS or is allowed to deviate from the 85th percentile speed between 8 to 16 km/h by most juristictions. Therefore, the posted speed limit for the studied roadways maybe considered equal to the observed 85$^{th}$ FFS lowered by 10 km/h and rounded up to the nearest 10km/h, which means the resulted posted speed limit is **80 km/h**. The reduction in value is attributed mainly to considerations of safety and partly to the fact that the data were collected during off peak periods wherein every vehicle with headway less than 5 seconds was excluded during the data abstraction. The obtained posted speed value explains the consistency with that concluded by MD. Deardoff, et. al. Their results reveal that average free-flow speeds are strongly associated with posted speed limits.

The relationship between the traffic flow (volume) and the average running speed (ARS) for the Al-Ramadi roadway network can be represented by the following equation;

$$\mathbf{ARS = 107.15 - 0.044*q}$$

The following findings can be concluded as in table 5:

TABLE 5. Concluded Findings.

| Traffic facility | Predicted model | Limitations |
|---|---|---|
| ARS versus traffic flow | ARS = 107.15 – 0.04*q | ✓ The road geometry is divided good paved with raised median.<br>✓ The maximum free traffic flow is 1100v/h. |
| ARS versus traffic flow with earth shoulders | ARS = 78.74 – 0.0058*q | |
| ARS versus Trucks% | ARS = 113.95 – .26*HV% | |
| Posted speed limit | 80 km/h | |

# Recommendations

1. The recommended posted speed limit for Al-Ramadi City should not reach the value of the $85^{th}$ FFS in order to keep the network operating safely and efficiently.
2. Based on the findings above, it is recommended to continue studying the selected roadways in order to predict any factors influencing the capacity to develop new criteria for the level of services and other factors. Transportation guidance and design policies are urgently needed in order to implement the first step to develop a local highway manual so as to enhance the efficiency and safety for the transportation network in the city.
3. AASHTO [7] recommends that the assumed design speed should be consistent with the speed a driver is likely to expect and should fit the travel desires and habits of nearly all drivers. Based on AASHTO recommendation and the obtained values of operating and average running speed, the design speed for the Al-Ramadi network is recommended to be equal to the average value of the 85th operating speed that is **(90 km/h).**
4. It is recommended for further study to collect data from another roadway network in Al-Ramadi City in order to validate the predicted equation mentioned above.

## Acknowledgments

This work is supported by the University of Anbar–Iraq (Renewable Energy Research Center) with Grant No. RERC-TP6.

## References

[1] S. Nikiforos, et.al., Analysis of inconsistencies related to design speed, operating speed, and speed limits, *KTC-06-12/SPR286-05-1F Research Report,* (2007).

[2] M. D. Deardoff, B. N. Wiesner, J. Fazio, Estimating Free-Flow Speed from Speed Limit Signs, *6th International Symposium on Highway Capacity and Quality of Service*, (2011), 306–316.

[3] A. M. Figuero and A. P. Tarko, Speed factors on two-lane rural highways in free-flow conditions, *Transport RES REC* **1912** (2005), 46–9.

[4] K. Fitzpatrick, P. Carlson, M. Brewer, M. Wooldridge, S. Miaou, Design, speed, operating speed, and posted speed practices. Report Submitted to Washington, DC., NCHRP504, (2003).

[5] Transportation Research Board, National research council highway capacity manual HCM, Washington, D.C., (2010).

[6] E. T. Donnell, K. M. Mahoney, and J. M. Mason, Conceptual approach to relate design speed, operating speed, and posted speed limits, *AB02H0501 Annual Meeting*, (2002).

[7] American Association of State Highway and Transportation Officials, A Policy on Geometric Design of Highways and Streets, (2011).

[8] Federal Highway Administration, U.S. Department of Transportation, Manual on uniform traffic control devices for streets and highways, Washington, D.C., (2011).

[9] ITE Technical Committee 97-12, Parma, K., chair, Survey of speed zoning practices, *ITE Informational Report, Institute of Transportation Engineers,* Washington, D.C., (2001).