



**ADDIS ABABA UNIVERSITY
ADDIS ABABA INSTITUTE OF TECHNOLOGY
SCHOOL OF CIVIL AND ENVIRONMENTAL ENGINEERING**

EVALUATION OF VEHICLE SPEED BREAKER PERFORMANCE IN ADDIS ABABA

**By
Mewded sifer**

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**Advisor
Getu Segni (Dr.)**

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ADDIS ABABA UNIVERSITY
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Approval by Board of Examiners:

_____	_____	_____
Advisor	Signature	Date

_____	_____	_____
Internal Examiner	Signature	Date

_____	_____	_____
External Examiner	Signature	Date

_____	_____	_____
Chairperson	Signature	Date

DECLARATION

First, I declare that this thesis is my original work and that all sources of materials used for this thesis have been properly acknowledged.

Mewded sifer

Name

Signature

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Abstract

Speed breaker is a common name for a family of traffic calming devices that use vertical deflection to slow motor-vehicle traffic in order to improve safety condition. Speed-breakers are considered as "Sleeping Police Officer" and self-controlling which helps in containing over speeding also as called speed bumps, speed humps speed cushion and speed table.

Over speeding is one of the main causes for traffic crashes across the world. Pedestrians are one of vulnerable for traffic crashes due to over speeding. Thus to reduce this speed (i.e. beyond the speed limit) as a solution Addis Ababa Traffic Management Agency at selected place Constructed speed humps. Speed hump are the most common type of traffic calming measure across the world due to their low cost and easy for construction. It was not made study whether the Constructed speed hump reduce traffic crashes and Vehicle speed effectively before here in Addis Ababa. There for; this paper intends to evaluate the performance of vehicle speed hump in Addis Ababa. To achieve the objective of the research, the collection of primary and secondary data was conducted. Primary data: Field observations carried out to observe road geometrics and design characteristics of the road humps. And spot speed survey was conducted to collect Vehicle speed at different location around speed hump. The spot speed data collection was carried out during week day. All this data was taken from 10:00 am. to 12:00 pm. as to avoid peak hour for traffic flow. The weather during the collection was sunny. Secondary data considering traffic Crash data before and after speed hump construction from 2009 to 2012EC from the selected site sub city depending on the construction period of speed hump.

The finding indicates that the speed humps contribute to reduce the vehicle speed that is before speed hump for all selected site (36-38 Km/hr.) which reduced to on speed hump (17-19 Km/hr.). And it forces most of the driver to drive with in speed limit. The 85th percentile speed of the observed vehicles travel on speed hump on each site that is (21-24 Km/hr.) which is below the posted speed limit (i.e. 30km/hr and 50Km/hr.). The design characteristics of the road humps are also an important factor in reducing the speed of the vehicles all the selected area height with in 75mm to 100mm. In addition to this from the finding the percentage of traffic crash reduces after the construction of speed hump by (29% - 58%) in all selected site. The findings also showed a clear difference in the average speed of the vehicles before the speed hump and on the speed humps.

And also from t-test result for traffic crash data before and after speed hump construction for all selected site calculated t- Value > t- critical ($t_{\alpha} (n-1)$) so it shows differences in mean of traffic crash data before and after the construction of speed hump on all study area at 95% confidence interval. As a result, for drivers to acquire good driving behavior change the contribution of speed hump is high.

Concerning on geometric characteristic of speed hump depending on the posted speed limit the length of speed hump 5m ,7.4m and 10.8m, height (100mm) and shape (Modified circular) on all studied area.

Keywords: speed hump, spot speed, traffic Crash



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1. INTRODUCTION

1.1 Background

Traffic crashes is increasingly growing and becoming worry of people's healthy globally. According to (WHO, 2018) global status road safety report, the number of annual road traffic death has reached 1.35 million and it is the leading killer of people age 5-29 years.

There are many reason to happen traffic crashes but as of the review related literature the most common causes of road traffic crashes that is over speeding, Alcohol and drug-induce driver, Reckless driving (i.e. impatience in traffic), driving without seat belt, not using helmet while driving motor cycle, Environmental factor (WHO,2018). Excess speed is defined as exceeding the speed limit. Inappropriate speed is defined as driving at a speed unsuitable for the prevailing road and traffic conditions. Excess and inappropriate speed is responsible for a high proportion of the mortality and morbidity that result from road crashes. In high-income countries, speed contributes to about 30% of deaths on the road, while in some low-income and middle income countries; speed is estimated to be the main contributory factor in about half of all road crashes (WHO, 2004).

An increase in average speed is directly related both to the likelihood of a crash occurring and to the severity of the consequences of the crash. For example, an increase of 1 km/hr in mean vehicle speed results in an increase of 4–5% of fatal crashes. And also Speed also contributes to the severity of the impact when a collision does occur. For car occupants in a crash with an impact speed of 80 km/hr, the likelihood of death is 20 times what it would have been at an impact speed of 30 km/h. (WHO, 2018)

An adult pedestrian's risk of dying is less than 20% if struck by a car at 50 km/h and almost 60% if hit at 80 km/h. (WHO, Mannagong speed, 2017) There is different way of speed controlling mechanism that is setting enforcing speed limit, speed camera and traffic calming measures According to (WHO ,2004) traffic-calming measures have been widely used to reduce crash frequency in many high income counters. That is construction of physical speed-reducing measure



or speed humps. And also according to (Archer, 2008) Speed breakers are considered as best and cost effective means to contain over speeding and safety of pedestrian.

Addis Ababa is the capital City of Ethiopia, with geographical coordinates of (9°01'28.80") North and (38°44'14.39") East and with an average elevation of 2355m above sea level. The City has a total area of about 527 km² and according to population stat,2017-2020 the population of Addis Ababa in urban area is 4,878,260. Data source World Bank, United Nation, Census a Geo names. The City is divided into 10 administrative sub cities and 116 woreda and it is the most important business and commercial center of the country.

In case of Addis Ababa, according to Addis Ababa Police Commission the traffic crash reports a total of 28361 and 29546 crash due to different reason have been occurred in 2018 and 2019.respectively in Addis Ababa. But out of these traffic Crash due to over speeding 2741 and 2361 occurred in 2018 and 2019 respectively. Studies have shown that speedy driving accounted for 13–50% of Road traffic causes in Ethiopia, Ghana, and Kenya. (Mr. Debela Deme, 2019).

To overcome this concerned authority of Addis Ababa as an alternative Constructed speed hump at the selected road. The raw data get from Addis Ababa police commission.

The main focus of this paper is to evaluate the effective performance of speed humps in reducing vehicle speed and it is evaluating the characteristic of road humps. And also evaluate in reducing traffic Crash.



1.2 Statement of the Problem

As per review related literature's and from the observation over speeding follows disasters traffic crashes especially in urban area (Authority, Irish R. S. (2011)). And also as all we know rising number of cars plying on the street poses risk primarily to the pedestrians and also it is risk for driver as traffic Crash at a time cost their lives. According to (WHO, 2015) Safety must lie at the heart of speed management bringing road users to a safe speed using an integrated set of measures.

By considering this new speed controlling device such as speed hump constructed in Addis Ababa, Ethiopia on the selected area. However, the effectiveness of the speed humps not assessing yet. There for this study focus to evaluate the effectiveness of the Constructed speed hump with respect to reduction of traffic crashes, vehicular speed and geometric characteristics of speed humps. Because from different study the geometric element of the speed hump such as, the length and height of humps should be precise to avoid difficulties for the drivers Besides, the road hump profiles mainly, height and spacing should be consistent which influencing the drivers' comforts (Hamsa,2017).

1.3 Research question

In order to find a solution for the problems due to Constructed speed hump which found in Addis Ababa, questions will be formulated as follows:

- Does the Constructed speed hump reduce occurrence of traffic Crash?
- Does the Constructed speed hump reduce the average speed and 85th percentile speed effectively?
- Does the design characteristic of the Constructed speed hump work properly?



1.4 Significance of the study

This study contributes the following key points:

- To identify the effectiveness of Constructed speed humps whether it full fills the intended purpose or not then indicates for the responsible body.

1.5 Objective of the study

Traffic calming systems that generally incorporate physical measures such as speed breaker, roundabout, road narrowing are design to reduce vehicle speeds. This research tried to see only speed breaker especially speed hump to evaluate the effectiveness for the selected are in Addis Ababa.

1.5.1. General objective

The general objective of the thesis to assess and evaluate the effectiveness of Constructed speed humps in Addis Ababa, with respect to reducing vehicular speeds, traffic Crash and geometric characteristics.

1.5.2. Specific objective

- To evaluate the effectiveness of constructed speed hump with respect to vehicle speed reduction and to check whether it reduce 85th percentile speed or not.
- To evaluate reduction of traffic crash before and after the construction of speed hump.
- To evaluate design characteristics including geometrical elements of the Selected road humps



2. LITRATURE REVIEW

2.1. Traffic calming

Traffic calming is the combination of mainly physical measures that reduce the negative effects of motor vehicle use, alter driver behavior and improve conditions for non-motorized street users. And the objective of traffic calming is achieving slow speeds for motor vehicles, reducing collision frequency and severity and reducing the need for police enforcement. (ITE, 1997). In addition to this systematic planning and evaluation procedure was developed to help in the assessment and selection of different calming measures. The procedure accounts for characteristics such as road hierarchy, area characteristics, environmental concerns, cost and ease of maintenance, and user safety (Mobushar, 1999).

One of the main tasks of institutions responsible for road safety is to ensure that the drivers comply with the speed limits. Norway serves as a good example of the leading country in the field of road safety, which among other road improvement tasks of road safety has set a target that by 2024 there would be 85% of drivers who will comply with the speed limits (AUDRIUS VAITKUS, 2017) This is particularly important in urban areas where pedestrian and bicycle traffic is high. Traffic calming measures, in particular, groups of measures, physically enforce drivers to comply with the speed limit. Traffic calming measures can be implemented individually or in combination. The effectiveness of the mentioned measures is highly affected by a proper selection of their type, distance between, and geometric parameters. (AUDRIUS VAITKUS, 2017).

This paper focus on one of traffic calming measure called speed hump. According to Addis Ababa city road traffic management in Addis Ababa get 10 roads which greatly susceptible to traffic crash which is selected depending on their record of causing at least 3 fatal crashes annually. Thus as a remedial measure the agency selects an asphalt type speed hump because of cost effectiveness, material availability and easiness to bond with asphalt road.

2.2. Speed breaker

Speed breaker is a common name for a family of traffic calming devices that use vertical deflection to slow motor-vehicle traffic in order to improve safety condition. Speed-breakers are considered as “Sleeping Police Officer” and self-controlling which helps in holding over speeding also as called



speed bumps, speed humps speed cushion and speed table (Dorji Peljor, 2016). There are various types of speed breaker as discussed below.

2.2.1. Speed hump

A Speed Hump is a vertical device with a raised parabolic shaped area in the roadway, extending across the road at right angles to the traffic. The raised surface is higher, and occurs over a shorter travel distance than for other vertical devices. Speed humps are the most commonly used traffic calming devices. Speed humps are one tool available in the traffic calming toolbox, and have gained acceptance by North American and international jurisdictions since their development in the early 1970s by the Transport and Road Research Laboratory (TRRL) in Great Britain. (Margaret Parkhill, 2007)

They are generally 10 to 14 feet (3.04-4.26 meter) in length in the direction of travel and are 7 to 10 cm high as shown in (Figure: 2-2). Thus making them different from the speed bumps. The profile of a speed hump can be circular, parabolic or sinusoidal. (MitulPatel1, 2017).

They are tapered as they reach the curb on each end to allow proper drainage. Speed humps are suitable where low speeds are desired. The speed humps are inexpensive and relatively easy for bicycles to cross if designed properly. It is designed to create a rocking motion that increases driver discomfort as crossing speed increases (Talaat Ali Abdel-Wahed a, 2017)



Figure 2- 1 speed hump

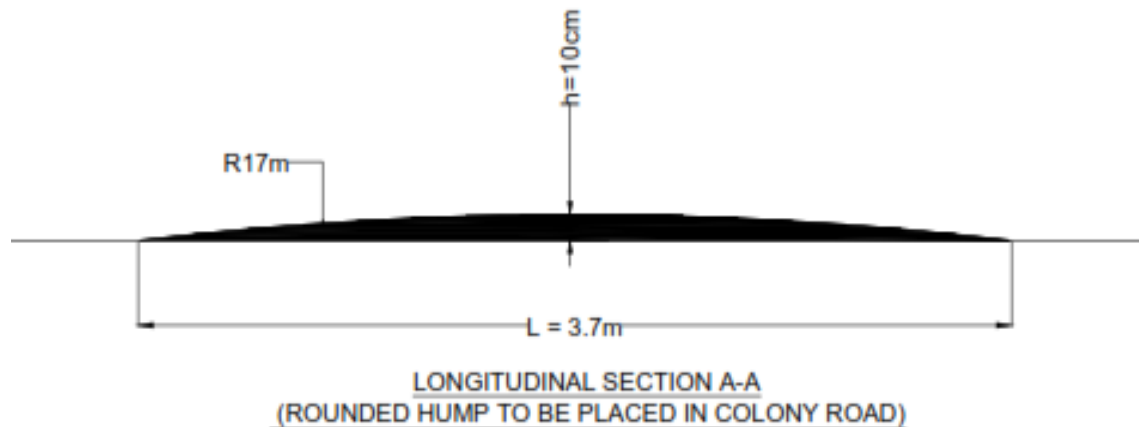


Figure 2- 2 longitudinal section of round top speed hump

The most common design of speed hump is the circular. Most vehicles can traverse them safely at (25-30km/hr.). The design of speed humps has evolved from extensive research and testing to achieve the specified speed reduction goal without imposing a high level of safety risks. When designed and constructed properly, speed humps can be effective at lowering vehicle speeds and possibly reducing speed-related collisions. Speed humps can also be constructed in a series to reduce speeds along an extended section of street. (Mitul Patel1, 2017).

2.2.1.1. Design characteristics and types of speed hump

The longitudinal profile of a road hump can be based on a segment of a circle; a sine waves or have a flat top with straight ramps up to the plateau. Local Transport Note 01/07 (March 2007).

Vertical deflections (road humps) were developed by TRL for the Department of Transport (DOT), now the Department of Environment Transport and the Regions (DETR). Trials were carried out on the test track at TRL using humps of various heights and profiles. These experiments resulted in the circular profile 'round top' hump of 12 feet long and 4 inches high (3.7 meters and 100 mm respectively, see Figure 2-2 above). (Layfield, 1998)

Other hump profiles have also been used to reduce passenger discomfort while still controlling vehicle speeds. Humps with a sinusoidal profile (sometimes called the bell shape hump) have been used in the Netherlands, Denmark and Scotland (see Figure 2-3&2-4). These humps are similar to

around-top hump but have a shallower initial rise. Further work in Denmark has led to the development of a modified sinusoidal profile. (Layfield, 1998)



Figure 2- 3 Example of a sinusoidal hump

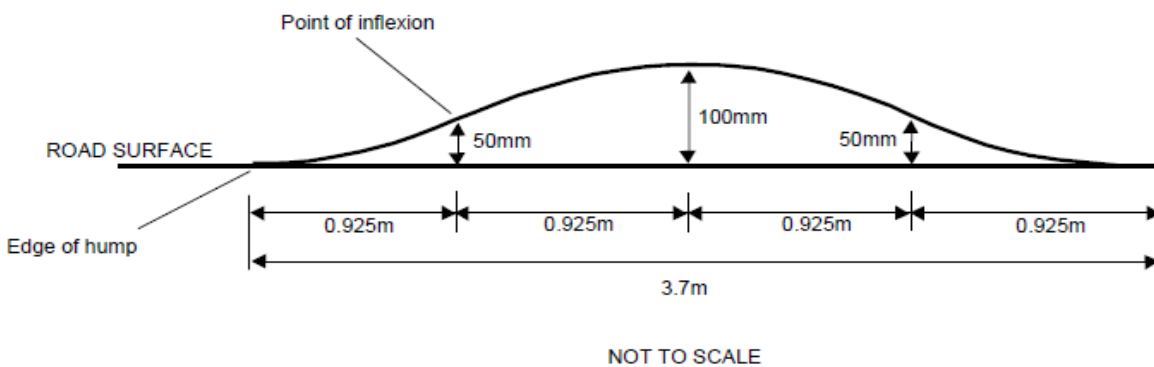


Figure 2- 4 Diagram of a typical cross section of

Source: (TRL377,1998)

The other type of hump profile is Modified round-top hump. Round-top humps with a longer cross-section in the direction of travel provide less discomfort at higher speeds and have been used in Denmark as speed controlling devices allowing higher speeds than the standard 3.7 m

round-top hump. Some of these round-top profiles have been modified by feathering the leading and trailing edges of the hump to reduce the initial rise (Lay field, 1998).

Trials of long round-top humps and round-top humps with feathered leading and trailing edges for use 40mph (64Kph) speed limit roads were carried out by Hampshire County Council and TRL in 1991 and 1992 (Lay field, 1998). The length of modified circle hump varies depending on the posted speed limit in that road such as for 40km/hr and 50km/hr the length of speed hump is 7.5m and 11m respectively. (World resource institute, 2015). Now a day this trained is done in Addis Ababa, Ethiopia.

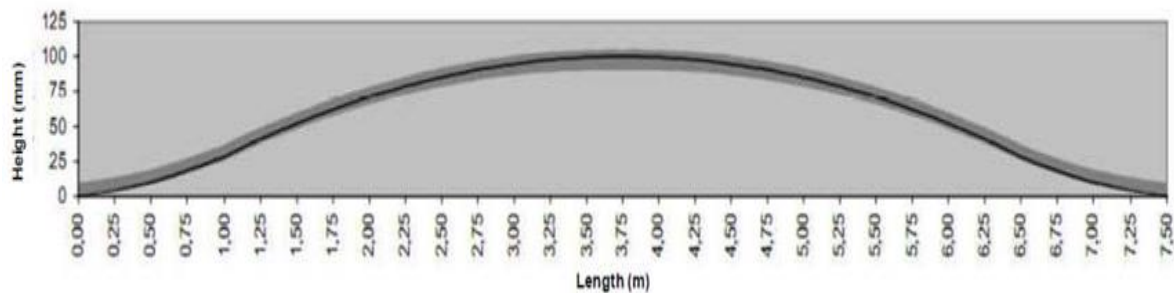


Figure: 2- 5 modified circle hump

Source: world resource institute, 2015

Since the above Hump profile is not suitable for all type of car it requires other type of hump profile which is The 'H' hump (Figure:2-6) was designed. Local Transport Note 01/07 (March 2007). as a combination hump (sometimes called a combi-hump) so that buses and cars could travel over the hump at similar speeds. Cars, which have a narrower track, have to use the steeper part of the hump, whereas buses, which have a wider track, are able to use the less severe outer ramps. This affects large buses and fire appliances, but may not be as effective for small ambulances or minibuses with narrower tracks. The 'H' hump has been used in the UK; the dimensions used are given in (Figure: 2-7) This shows that the outer ramps are 1 in 24 and the inner ramps 1 in 12, with an overall height of 75 mm and a plateau length of 7 meters.

LocalTransportNote01/07(March,2007)



Figure 2- 6 Plan view and cross-section of an 'H' road hump

Source: Local TransportNote01/07(March,2007)

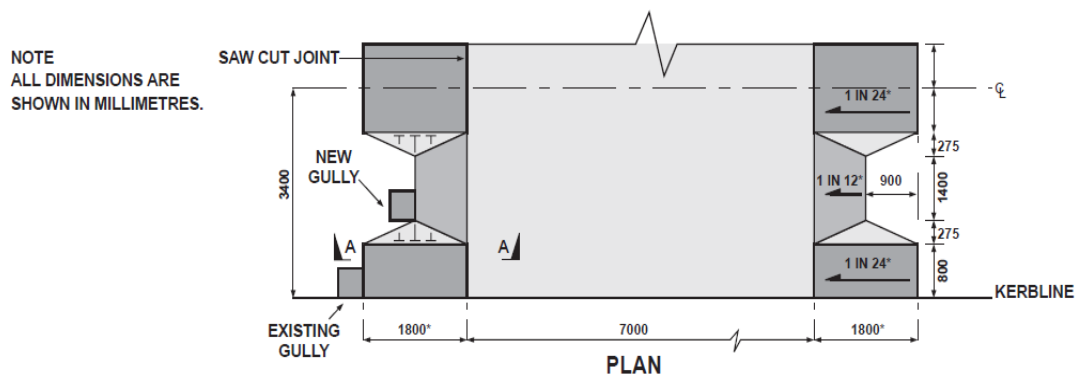


Figure: 2- 7 'H' hump at a raised zebra crossing

Source: (TRL377, 1998)

The 'S' hump (Figure 2-8) was designed by Fife Council in Scotland, using a similar principle to the 'H' hump described above. The 'S' hump dimensions used by Fife are given in (Figure2-9). This shows that the minimum gradient for the outer ramps are 1 in 33 and the maximum inner ramp gradients are 1 in 8, with an overall height of 75 mm and a plateau length of 7 meters. Vehicles with a narrow track have to use the steeper part of the hump, whereas those with a wider track are able to use the less severe outer ramps. This benefits large buses and fire appliances but may not be as effective for small ambulances or minibuses with narrower tracks. The 'S' hump could be used in a speed cushion scheme, where raised junctions or pedestrian crossings are required.

A spacing of 100 meters was found to be acceptable for the 'S' road humps in Fife: Local Transport Note 01/07 (March, 2007). The speed differential between buses and cars was similar to the 'H' hump.



Figure 2- 8 'S' road humps

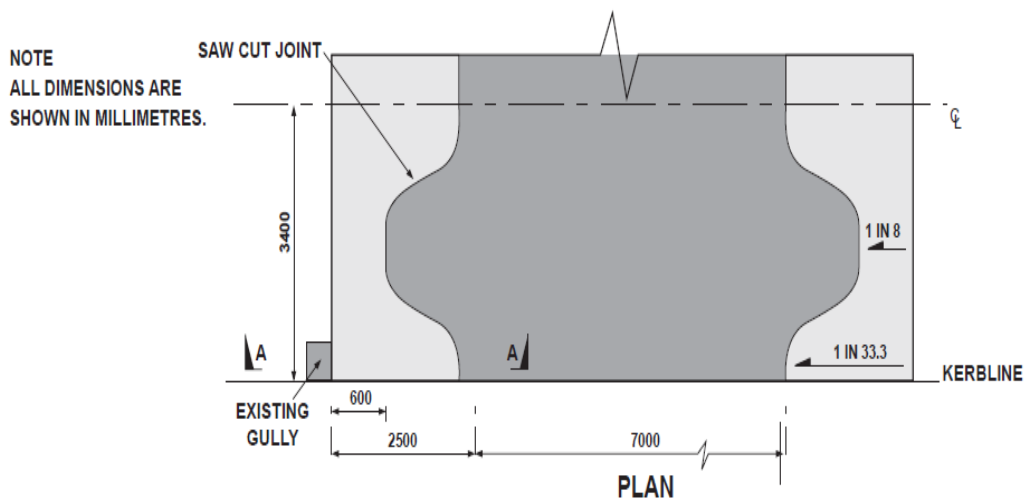


Figure 2- 9 Plan view and cross-section of an 'S' road hump

Source: Local Transport Note 01/07 (March, 2007)

2.2.2. Speed bump

Speed bumps are the device that uses the vertical deflection on the road to slow down the moving traffic. They are suitable to reduce speeds of the vehicles to around 40kph for roads and/or 8 to 16kph for car parking. They are generally 1to3 feet (30.04 to 91.4 centimeter) long and 7 to 15 cm high as shown (Figure 2-10).



Figure 2- 10 Speed bump

The speed bumps reduce speed considerably, avoid crashes and reduce severity of crash. However, the provision of bumps may cause significant discomfort to drivers as well as passengers, increased damage to the vehicle, increases response time of emergency services, it requires additional road markings and traffic signs and it causes increase in traffic noise and pollution. (Mitul Patel1, 2017)

2.2.3. Speed table

Speed tables are flat-topped speed humps and are long enough for the entire wheelbase of a passenger car to rest on the flat section. Their long flat fields give speed tables higher design speeds than Speed Humps. They are 22-24 feet (6.7-7.3 meter) long and 7-10 cm height. And are good for locations where low speeds are desired with smooth ride for larger vehicles. If pedestrian

markings are used over the flat section, it is referred as raised crosswalk. They can be expensive and may increase noise and air pollution. (Mitul Patel1, 2017)

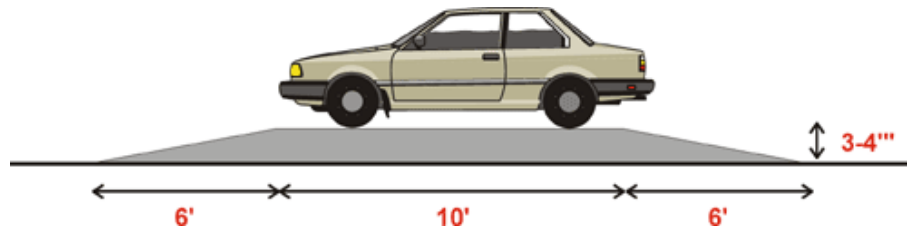


Figure 2-11 Speed table

2.2.4. Speed cushion

Speed cushions are a type of speed hump designed to avoid the negative impacts that vertical deflections have on emergency vehicle response times. Speed cushions are made up of several small speed humps constructed across the width of the road with spaces between them as shown in the (Figure 2-12). They force normal cars to slow down as they ride with one or both wheels over the humps. Meanwhile, they allow fire engines and other large vehicles with wider axles to straddle the cushions without slowing down. Thus it results in movement of emergency vehicles as well as heavy vehicles with no discomfort to vehicle occupants and no delays. (Mitul Patel1, A study on Speed Breakers, 2017)



Figure 2-12 Speed cushion

2.3. Speed breaker and over speeding

Over speeding or inappropriate speed are responsible for a high proportion of the mortality and morbidity that result from road crashes (WHO,2004). The speed limit is normally set below the design speed of the vehicles to minimize the frequency of unsafe conditions encountered by those drivers that, for what reason, choose to exceed it (Hamsa1, 2013). Speed is a demonstrated road collision causal factor in about one in every three fatal collisions. The 18% of car drivers exceeding speed limit on rural roadways, in 2011. Furthermore, 82% of car drivers surveyed exceeded the 50km/h limit on urban national roads. The survey found that overall driver compliance with speed limits on urban roads (excluding residential roads) is still poor. On average, 3 out of 5 motorists exceeded the posted speed limit in urban areas. (Authority, 2011)

According to (WHO,2004) in high income countries, speed contribute to about 30% of deaths on road, while in some low income and middle income countries, speed is estimated to be main contributory factor in about half of all road Crashes. In Addis Ababa, Ethiopia according to traffic police report, traffic crashes due to over speeding in 2017 and 2018 was 1922 and 2741 respectively. So it is increased by almost 32%.

Speed hump is the most widespread traffic calming devices because of its effect in speed reduction and low cost. In the case of city of Albuquerque, 96% of all devices are speed humps, West Sacramento, California, 85% of the devices are speed humps and Largo, MD 75% of the devices are speed hump (Farzana Rahman, 2007)

Research has shown that properly designed and Constructed speed humps can reduce vehicle speeds to 23.4-31.2 km/h when traversing speed humps and 39-46.8 km/h in between properly spaced speed humps (Farzana Rahman, 2007)).In addition to this the Studies done in Australia, the United Kingdom and the United States, indicated reductions in 85th percentile speeds in the range of 3 to 14 mph between the humps and 6 to 27 mph at the hump. (Hamsa, 2017).

In Bellevue, Washington, sixteen speed humps were constructed in five residential neighborhoods. Prior to construction, the 85th percentile speeds were 58 to 63 km/h (36 mph to 39 mph). After construction, they went down to 39 to 43 km/h (24 to 27 mph). (Cynecki,



2000) Speed humps in Montgomery County, Maryland, typically reduced 85th percentile speeds by 6.6 to 11.7 km/h and reduced crash frequency (Cynecki, 2000). Five speed humps were built along a half-mile (0.8-km) stretch of Grey Rock Road in Agoura Hills, California and the 85th percentile speeds fell by 10 to 15 km/h after the humps were installed. (Cynecki, 2000). In three Australian cities, Corio and Croydon in Victoria and Stirling in Western Australia, the 85th percentile speeds at speed humps dropped by half or more after speed hump construction. (J. Cynecki, 2001).

A study in residential areas in North America showed the average percentage change of 85th percentile speed after the construction of road hump is approximately 23%. Similarly, another study in 2004 discovered that the average speed is reduced from 36.4 to 24.4 km/h; a reduction of 33% after the implementation of road humps in residential areas (Hamsa, 2017)

2.4. Impact of speed hump

According to (01/07, Traffic calming, 2007) One problematic aspect of speed humps is their effect on emergency vehicles. Emergency services – physical speed-reducing measures can adversely affect the response times of emergency services vehicles. This is particularly relevant to fire and ambulance services.

Emergency responders have also voiced their concerns about the hazards speed humps pose for them. They must reduce their travel speeds to navigate over a speed hump and consequently, emergency response times can be reduced by up to 10 seconds (Werner, Tanisha, 2015).

The presence of such humps has a negative impact on roadway level-of-service, as they increase travel time and delay. They also may cause serious damages to vehicles and passengers, and increase fuel consumption and pollution. Moreover, these improper speed humps may deteriorate the pavement condition, before and after the location of hump, due excessive acceleration and deceleration movements, and might be a factor in reducing the pavement service life (Talaat Ali Abdel-Wahed a, 2017).

Speed humps cause a rough ride for drivers as well as passengers and can cause severe pain for people with certain skeletal disabilities. They force large vehicles, such as emergency vehicles and



those with rigid suspensions, to travel at slower speeds, they may increase noise and air pollution and have questionable aesthetics (Mitul Patel1, 2017)

Advantage	Dis-advantage
speed reduction	Emergency response delay
Volume reduction	Traffic diversion
Crash frequency reduction	Liability concern Aesthetics
Crash severity reduction	maintenance difficulty
crime reduction	Noise

Table 2- 1 Advantage and dis-advantage of speed humps

Source: (Dan Smith Shauna Hallmark, 2002)

2.5 Spot speed measurement

Spot Speed studies are conducting to estimate the distribution of speeds of vehicles in a stream of traffic at a particular location on a highway by carried out recording the speeds of a sample of vehicles at a specified location. Spot speed data are gathering by using a speed measurement device – a hand-held digital radar gun known as Laser Technology.

This technology is selecting because it is the latest technology that found on some selected sub city in Addis Ababa that given from Addis Ababa Federal police commission.

Laser Technology is velocity speed gun is able to measure automobile speeds between 0 and 320km/h from maximum measurement distance as far as 1,200 meters. To ensure accurate readings, the path of the emitted radar from the device must coincide with the path of the automobile as closely as possible. Error increases as the angle of the reading diverges from the vehicle path. By attempting to approximate a straight-on path of measurement, readings have an accuracy of ± 2 km/h (Laser technology manual, 2013).





Figure 2- 13 a hand-held digital radar gun (Laser Technology)

3. Research methodology

3.1. Study area

Addis Ababa is the capital City of Ethiopia, with geographical coordinates of (9°01'28.80") North and (38°44'14.39") East and with an average elevation of 2355m above sea level. The City has a total area of about 527 km². And according to population stat, 2017-2020 the population of Addis Ababa in urban area is 4,878,260. Data source World Bank, United Nation, Census a Geo names. The City is divided into 10 administrative sub cities and 116 woreda and it is the most important business and commercial center of the country.

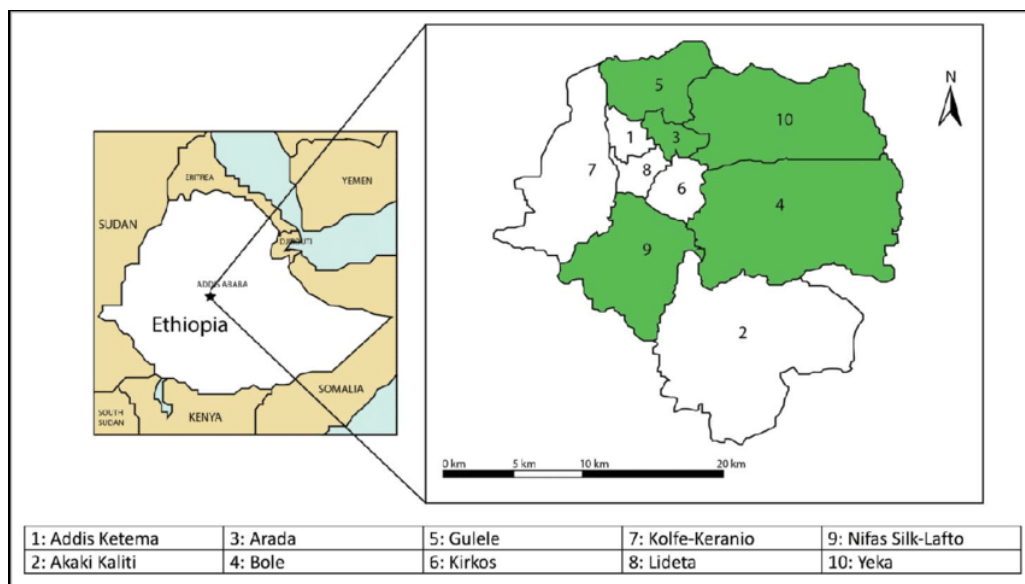


Figure 3- 1 Maps of Addis Ababa with Administrative sub city

In the case of Ethiopia, according to Addis Ababa Police Commission the road traffic report of total of 28361 and 29546 crashes have been occurred due to different reason in 2018 and 2019 respectively in Addis Ababa. The raw data get from Addis Ababa police commission are attached on the appendix A. Studies have shown that speedy driving accounted for 13–50% of Road traffic causes in Ethiopia, Ghana, and Kenya. (Mr. Debela Deme, 2019).

To overcome this AARTMA (Addis Ababa city Road Traffic Management Agency) as an alternative currently in addition to other traffic calming Constructed speed hump on the selected road based on susceptibility of traffic crash. As of information get from Addis Ababa city Road Traffic

Management Agency the speed hump constructed on 65 sites within two years on Addis Ababa road having speed limit 30Km/hr, 40Km/hr and 50Km/hr. The number of site on which speed hump is constructed from May, 2010 to Jun, 2011 are 30 sites. The rest constructed from September, 2012 till May, 2012.

In order to evaluate the performance of speed hump constructed in Addis Ababa, the researcher observes the study area and selected the study area based on the posted speed limit on the street and susceptibility of traffic crash after discussion of Addis Ababa city Road traffic management Agency. The seven selected study areas are illustrated as shown below Google earth image and Photo take on each site.



Figure 3-2 Sidest kilo to Afencho ber relative location map

Source: Google earth



Figure 3- 3 Speed hump on sidest kilo to Afencho ber

Source :photo take on site

For the rest selected study areas are illustrated as shown on Appendix B:

3.2. Study design

In order to evaluate the effective performance of speed hump for the selected location the researcher use spot speed study, it is required to collect the spot speed data. Before approaching speed hump, at hump and after passing speed hump using Laser Technology. The behavior of the drivers when approaching, on the speed humps and after passing speed hump was observed at sites during preliminary study. Through this observation, the locations for taking the spot speed data can be recognized. The place where the spot speed of cars approaching the humps with free flow speed which is no influence from the existence of humps is taken by observing the distance before the driver starts to reduce their speed and after passing speed hump, after starting to increase its speed. Thus in this study, the free flow speeds were taken from 10:00 am. To 12:30 pm. as to avoid peak hour. For traffic flow before the hump and after speed hump were taken at a distance of 50m from speed hump based on observation during site visit and stopping reaction distance equation.

As well field survey this is to take the geometric element of speed hump that is the height, length and width using ruler and tape respectively. Beside take the spacing between hump. And also take the traffic Crash data from different sub city on the selected road where Constructed speed humps are found before and after speed hump construction. Then by using the selected methods of analysis the data are reduced and analyzed. After that based on the output of the analysis discussing about the effectiveness of the Constructed speed hump and indicate for the concerned body.

3.3 Sample size and sampling technique

3.3.1 Sample size for speed hump

As of information get from Addis Ababa city Road Traffic Management Agency the speed hump installed or constructed with in two years on Addis Ababa road having speed limit 30Km/hr,40Km/hr and 50Km/hr are on 65sites and the geometrical characteristics of this hump are for each stratum or sub population are similar that is the length of the hump are 5m,7.5m and 10.8 m respectively. Besides the height for speed hump 40Km/hr ,30Km/hr and 50 Km/hr is 0.1m. The number of site on which speed hump is constructed from May, 2010 to Jun, 2011 are 30 sites. The rest constructed start from September, 2012. So to include this site on the research the traffic crash data after construction of speed hump is not sufficient to be reliable. So the researcher decides to take speed hump constructed from May, 2010 to Jun, 2011 of 30 sites to acquire representative sampling.

To do so the researcher use proportionate stratified random sampling. Which is in proportionate stratified random sampling, the size of each stratum is proportionate to the population size of the strata when examine across the entire population. This means that each stratum has the same sampling fraction. This sampling method is greater precision than simple random sampling because in the final sample better coverage of population to control on the sub groups.

The researcher stratified the sample as speed hump for 30 Km/hr, speed hump for 40 Km/hr and speed hump for 50Km/hr.



As a result, the researcher takes $\frac{1}{2}$ (Half from each stratum) on which road speed limit having 30km/hr 40km/hr and 50Km/hr. which is based on the following stratified random sampling:

Sample size of speed hump is determined by using the following stratified random sampling Equation,

$$N = \sum_{i=1}^K N_i$$

Where:

N: population size

K: number of strata

N_i : Number of sampling units i^{th} strata

$$n = \sum_{i=1}^K n_i \quad : \text{ Total sample size}$$

$$n_i = (N_i/N) * \text{stratum take} \dots \dots \dots \text{Eq.1}$$

Where:

n_i : Number of sampling units to be drawn from i^{th} strata

The speed hump constructed from May, 2010 to Jun 2011 as discuss before geometrical characteristics of this hump are for each stratum or sub population are similar length and height on 30 sites. Among this 8 sites are speed limit 30Km/hr, 16 sites are speed limit 40Km/hr and the rest 6 sites speed limit 50Km/hr.

There for:

When proportionate each Sub population takes $\frac{1}{2}$ (Half) of each stratum

$$\text{For 30km/hr.}; 8 * \frac{1}{2} = 4$$

$$\text{For 40Km/hr.}; 16 * \frac{1}{2} = 8$$

$$\text{For 50Km/hr.}; 6 * \frac{1}{2} = 3$$

Then substitute this value on

$$\text{For 30km/hr.}; (8/30) * 4 = 1.1 \sim 2$$

$$\text{For 40Km/hr.}; (16/30) * 8 = 4.26 \sim 4$$

$$\text{For 50Km/hr.}; (6/30) * 3 = 0.6 \sim 1$$



$$n = \sum_{i=1}^K n_i$$

$$n = n_1 + n_2 + n_3$$

$$= 2 + 4 + 1 = 7$$

- There for the representative sample size of speed hump site is 7

3.3.2 Sample size for Vehicle for spot speed study

The number of sample in this study was obtained from (Robert V. Krejcie and Daryle W. Morgan, 1970,) formula,

$$n = \frac{Z^2}{e^2} * p * (1-p)$$

n= sample size

Z=confidence interval =1.96

P=degree of variability =0.5

E= precision rate=0.05

In this research a confidence level of 95% ($Z = 1.96$) is use as this is the level use most commonly in engineering researches, and since the variability is unknown, a degree of variability of 0.5 is use because the statistician assigns the values as 0.5 (Bluman, 2009). And a precision rate of 5% is select, thus the sample size become 385 but the researcher taken 300 cars as samples for the spot speed data collection for each selected road site having speed hump. And it is distributing for each place that take for the study that is 100 cars before approaching speed hump, 100 cars at speed hump and 100 cars after passing the speed hump for each hump.

According to different studies for a spot speed study at a selected location, a sample size of at least 50 and preferably 100 vehicles is usually obtained (Arash Morad khani Roshandeh*, 2009). Besides according to (Dr. Tom V. Mathew, 2014) generally, sample sizes of 50 to 200 vehicles are taken for spot speed study. In that case, standard error of mean is usually under the acceptable limit. If precision is prior then minimum number of sample should be taken, that can be measured by using the following equation.



$$n_r = \frac{(Z_{\alpha/2})^2}{s e^2} \dots\dots\dots 6.3.1$$

where:

n_r is the no. of sample required,

δ is the Standard deviation

$Z_{\alpha/2}$ is value calculated from Standard Normal Distribution Table for a particular confidence level, since, the researcher desired to estimate, with 95% confidence interval (i.e. for 95% confidence $Z_{\alpha/2}=1.96$)

Se is the permissible (acceptable) error in mean calculation.

when Substitute in equation 6.3.1. Then it gives this result for vehicle. (i.e. $n=80$) but

to be more accurate the researcher takes 100 vehicles that is small cars for each location.

The researcher uses systematic sampling technique method for this study; systematic sampling method, each element in the population has a known and equal probability of selection. Using the systematic sampling method, every 5th road user (which include car that pass the selected road hump) selected as samples and the procedures was continued until 100 samples will be collected on each hump.

3.4 Method of data collection

To achieve the aim of the study and to answer the formulated research questions, different data are required, and these data are categorized into two; primary data and secondary data:

I. Primary data

3.4.1 Speed Surveys

Spot speed survey required to understand the users' driving behaviors in terms of reducing speed whenever approaching a road hump. The behavior of the drivers when approaching, on the speed humps and after passing speed hump was observed at sites in the preliminary study. Thus through this observation and from different study, the locations for taking the spot speed data can be identified.

The location where the spot speed of cars approaching the humps with free flow speed taken as first point that is 50m before speed hump. This is no influence from the existence of humps that



taken by observing the distance before the driver start to reduce their speed. The speed where the cars drive on the road hump taken as second point also been collected in this study then the third point taken after passing speed hump where the vehicle become accelerated.

The spot speed data measured by using a speed measurement device – a hand-held digital radar gun known as Laser Technology. Spot speed data was taken from 10:00 am. To 12:30 pm. as to avoid peak hour for traffic flow. This is because free flow speed of vehicle in actual situation when approaching and passing through the road hump can be obtained during off-peak hours. The weather during the collection was sunny.

3.4.2 Site Visit

Geometric element of speed hump survey

In this study, site visit would be made to collect data on the selection of road and road humps. The site visit would also be made to identify the general issues and problems of the selected area. The design profiles and characteristics of the road hump such as shape, length, width would also be collected. The site visit will be carried out during weekday. The observations on the images of road network and road humps will be recorded by using a camera; measurement of design characteristics of road hump and road geometrics by a measurement tape.

The geometric element of speed hump that is the height using ruler, length and width of the hump taken using tape meter and the spacing between the hump is also taken using tape meter.

II. Secondary data

3.4.3. Traffic Crashes survey

Traffic Crashed data related to speed collected from each selected road site which found on Addis Ababa where speed humps were constructed. Such as; on Gulele sub city, Yeka sub city, keranyo sub city and Nifas silk sub city. The collected data focused on motorist crashes before and after the speed hump constructions. Traffic Crash data collected from 2009EC up to 2012EC. That is depending on the period of construction of speed hump, the collected data for each sub city have been difference in number of months, such as Traffic Crash on Gulele sub city; from Sidest kilo to Afincho ber Traffic Crash data taken ten months before and after speed hump construction , Yeka



sub city; from Aware RA to Balderas condominium traffic Crash data taken ten months before and after speed hump construction and from Kara to Wesson taken thirteen months before And after construction of speed humps of traffic Crash data but for Keranyo sub city ; from Betel RA to keranyo RA traffic Crash data taken Fourteen Months before and after construction of speed hump ,form to Anfo RA Keranyo RA thirteen months Before and after construction of speed humps and Ayer tena to Jemo Michel traffic data taken thirteen months before and after construction of speed hump. Moreover, From Nifas silk sub city; road start from Bistrate Gebrel to Abo round about taken twelve months before and after the construction of speed humps.

3.5 Data analysis method

3.5.1 Traffic Crashes Analysis Method

Generally, the traffic Crash data that collected from each site on its sub city found in Addis Ababa, such as Gulele sub city, Yeka sub city, keranyo sub city and Nifas silk sub city for the selected speed hump before and after speed hump construction analyze using a method called paired t-test.

A paired t-test is used to compare two population means where you have two samples in which observations in one sample can be paired with observations in the other sample

To achieve the objective of the research using the selected method of data analysis uses the following steps;

- Collect the traffic crash data before and after speed hump construction
- Rearrange the data as required
- Put the hypothesis as follows:

Paired t-test

H₀-the Constructed speed humps do not have effect on the reduction of traffic crash such as:

$$\text{Null hypothesis: } H_0: \mu_D = \Delta_0$$

where $X - Y$ is the difference between the first and the second observation within a pair,

$$\mu_D = \mu_1 - \mu_2 ; \mu_D - \text{mean difference}$$



H_1 - the Constructed speed humps have effect on the reduction of traffic crash

Alternative hypothesis Rejection Region for level α Test

$H_1: \mu_D > \Delta_0$	$t \geq t_{\alpha, n-1}$
$H_1: \mu_D < \Delta_0$	$t \leq t_{\alpha, n-1}$
$H_1: \mu_D \neq \Delta_0$	$t \geq t_{\alpha/2, n-1}$ or $t \leq t_{\alpha/2, n-1}$

Then after setting the hypothesis the calculation is proceed as follows

- ✓ Calculate the difference ($d_i = y_i - x_i$) between the two observations on each pair,
- ✓ Calculate the mean difference, \bar{d} .
- ✓ Calculate the standard deviation of the differences, s_d , and use this to calculate the

standard error of the mean difference, $SE = \frac{s_d}{\sqrt{n}}$

- ✓ Calculate the t-statistic, which is given by:

$$T = \frac{\bar{d}}{SE(d)}$$

Under the null hypothesis, this statistic follows a t-distribution with $n - 1$ degrees of freedom.

- ✓ Use tables of the **t-distribution** to compare value for **T** to the t_{n-1} distribution. That gave the **p-value** for the paired t-test.

This is also done using SPSS software:

- The imputes for this software is the summarized collected data that is traffic Crash data before and after speed hump construction
- The output from the software is as follows:
 - Mean
 - Std. Deviation
 - Std. Error Mean
 - 95% Confidence Interval of the Difference
 - T



- D_f
- P-value

After all, depending on the above result decide whether the hump is effective or not in reducing traffic Crash in addition to this the researcher calculate the percentage decrease of traffic Crash after construction of speed hump.

3.5.2 Spot Speed Analysis Method

The spot speed data was analyzed by calculating the mean speed, median speed and modal speed. The mean, median and modal speed is calculated by using the following expressions:

$$\text{Arithmetic mean Speed, } X = \frac{\sum f_i x_i}{\sum f}$$

X = arithmetic mean of all recorded cars' speed

$\sum f_i x_i$ = Sum of frequency times the middle speed of each class

$\sum f$ = total frequency

The median speed is obtained from the cumulative frequency distribution curve. The mode or modal speed is obtained from the frequency histogram.

The calculation of average speed is to interpret the relationship between road humps' characteristics and the speed of cars. A cumulative frequency curve (upper limit speed vs cumulative frequency) will also be prepared to determine 50th and 85th percentile. The output from the analysis is expected to ascertain to what extent the provision of road humps reduces the speed of the vehicles along selected streets.

The existence of the statistical differences in the average speed of the vehicles at the selected points can be tested by using t-test. A t-test will apply to test the statistical differences in the mean speed of the vehicles traveling 50m before the road hump and on the road hump for the selected area.

We use SPSS software to check the speed hump whether reduce the vehicle speed or not.



- The inputs of software for this study is the collected spot speed data before approaching speed hump and on speed hump
- The output from the software is as follows:
 - Mean
 - Std. Deviation
 - Std. Error Mean
 - 95% Confidence Interval of the Difference
 - T
 - Df
 - P-value

After all, depending on the above result decide whether the hump is effective or not on reducing vehicle speed.



4. ANALYSIS AND FINDINGS

The analysis and result include field study result, traffic Crash before and after speed hump construction analysis and result and spot speed before reaching speed hump, at speed hump and after passing speed hump analysis and its result. First, field study result to describe about the selected road and the speed hump which Constructed in that road. Second the spot speed analysis and result then check the effectiveness of the selected speed hump with respect to speed. Third traffic Crash analysis and result then check whether the speed humps reduce traffic crash effectively or not.

4.1. Field survey result

4.1.1. Road geometrics of Sidest kilo to Afincho ber

General description of Sidest kilo to Afincho Ber Street

From the observation the geometrical design of selected road is straight road with construction of two speed humps along the road. The road (i.e. Sidest kilo to Afincho ber) was dual carriage way and four lanes in each way (3.5m width per lane). Speed hump construction was done in one direction road from Sidest kilo to Afincho ber but rumble strip Constructed on both directions. There for, only one direction is selected for this study. This road connected to the major road from Sidest kilo to Arat kilo which starting from UTM and ADINDAN coordinate (473073.9623, 999671.1594) end on coordinate (473614.6352, 999509.9223). It is under drain drainage system. And pedestrian walk way was 4.5m. in general the road has been under DS1 ERA Geometric Design Manual-2002.

4.1.1.1 General geometric description of speed hump design and its characteristics

From the general observation it has two speed humps and three rumble strip that used to alert the driver along the selected road (i.e. Sidest kilo to Afincho ber). for this study from this street take one speed hump as shown (Figure 4-1) bellow.

The indicted speed limit along the selected road was 30 km/hr. And the warning sign also contains there is speed hump ahead as shown the Figure (4-2) below and the warning sign on this site



placed at a distance of 62m from the speed hump. The warning signs were either mounted on signposts or banded to existing utility poles.



Figure 4- 1 Speed Hump Warning Sign

Source: photo takes on site

During observation Sidest kilo to Afincho ber road site actual measurement indicated that hump width 13.6 meter, length 7.45 meter and 100 millimeter height at the center and it is tapered humps (humps that are not completely curb-to-curb so the channel width on each side 200mm as shown the (Figure 4-3) below. the hump has been located at a distance of 360 meters from Sidest kilo round about. Moreover, adequate road markings and signing was placed in advance of and on the hump that guide subsequent movements. Furthermore, there is installed road studson hump also has make visible at night (Figure 4.4) below. The second speed hump and rumble strip was located at a distance of 240 meter and 136 meter respectively from the first road hump the following table shows the recommended space between hump. (Traffic Calming Design Guideline 11.07.07. Version 1 / July 2007).

According to (National Association of City Transportation Officials, 2021), Spacing for vertical speed control should be determined based on the target speed of the road way. Speed hump

should be spaced no more than a maximum of 152 m apart to achieve an 85th percentile speed of 25-35mph.

For local roads, speed humps are usually Constructed (137-228 meter) apart. (Ewing, 1999) .

Desired speed	Distance between humps
50 km/h	250 m
40 km/h	100 m
30 km/h	75 m

Table 4- 1 recommended relationship between desired speed and spacing of hump

Source: (Traffic Calming Measure Guideline11.07.07. Version 1, 2007)

OR The California Subcommittee of the California Traffic Control Devices Committee developed the following equation to determine optimal spacing between speed humps:

$$H_s = 0.5[2(V_{85}) (V_{85}) - 700]$$

H_s = optimal spacing between 3-inch (0.0762m) high speed humps (in feet)

V₈₅ = desired 85th percentile speed (in miles per hour) between speed humps

Source: (Dan Smith Shauna Hallmark, 2002)

The actual dimension of the speed hump on Sidest kilo to Afincho ber during observation is shown the table 4-2 below.

Road hump on	Width(m)	length(m)	height(mm)
Sidest kilo to Afincho ber	13.6	7.45	100

Table 4- 2 Dimension of hump on sadist kilo to Afincho ber





Figure 4- 2 Dimension on actual measurement

Source: photo takes on site



Figure 4- 3 Reflectors on hump

Source: photo takes on site

The actual measurements on a hump, as shown profile and picture below.

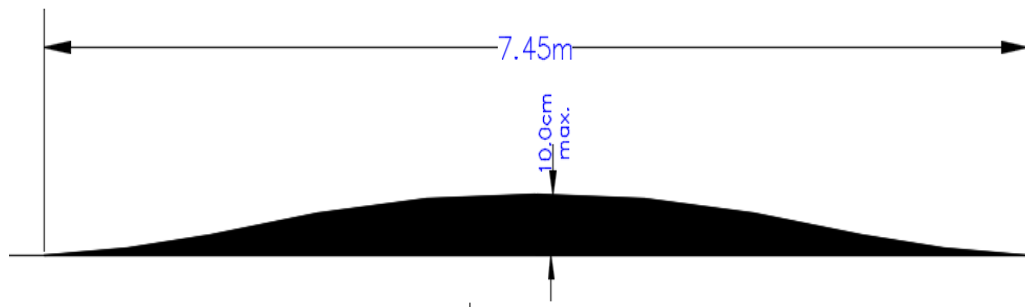


Figure 4- 4 Distance in actual site

4.1.2 Road geometrics of Aware round about to Balderas condominium

General description of aware round about to Balderas condominium

From the observation the geometrical design of selected road is straight road with construction of one speed humps along the road. The road (i.e. Aware round about to Balderas condominium) was two ways and two lanes (3.5m width per lane). Speed hump Constructed on both direction roads from Aware round about to Balderas condominium with rumble strip. Only one direction is selected for this study. This road connected to the major road from kebena to parlama which starting from UTM and ADINDAN coordinate (475300.7996, 997643.7829) end on coordinate (476177.0352, 997778.1786). It is under drain drainage system. And pedestrian walk way was 2.5m. In general, the road has been under DS2 ERA Geometric Design Manual-2002.

4.1.2.1 General geometric description of speed hump design and its characteristics

From the general observation the road has one speed humps and one rumble strip that used to alert the driver along the selected road (i.e. Aware round about to Balderas condominium). For this study from this street take one speed hump.

There is no any indicated speed limit along the selected road and also there is no any indicated warning sign to know whether there is speed hump ahead or not. During observation Aware round about to Balderas condominium site actual measurement indicated that hump width 6.7 meter, length 5 meter and 100 millimeter height at the center and it is tapered humps (humps that are not completely curb-to-curb so the channel width on one side 200mm and on the other side 100mm as shown the (Figure 4-15) below. The hump has been located at a distance of 640 meters

from Aware round about. And it has, adequate road markings were placed in advance of and on the hump that guide subsequent movements.

Furthermore, there is Installed road studs on hump also has make visible at night (Figure 4-6) below. The actual dimension of the road hump on Aware round about to Balderas condominium, during observation are shown the (Table 4-8) below.

Road hump on	Width(m)	length(m)	height(mm)
Aware round about to Balderas condominium	6.7	5	100

Table 4- 3 Dimension of hump on Aware round about to Balderas condominium

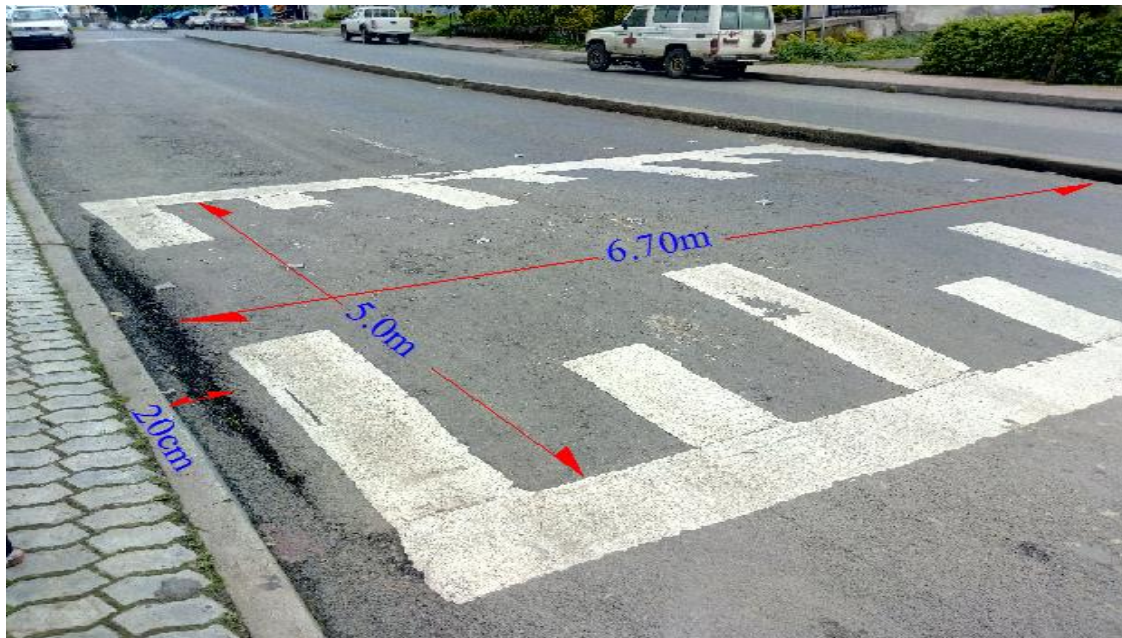


Figure 4- 5 Dimension on actual measurement



Figure 4- 6 Road studs on hump

Source: WRI, improving road safety in Addis Ababa

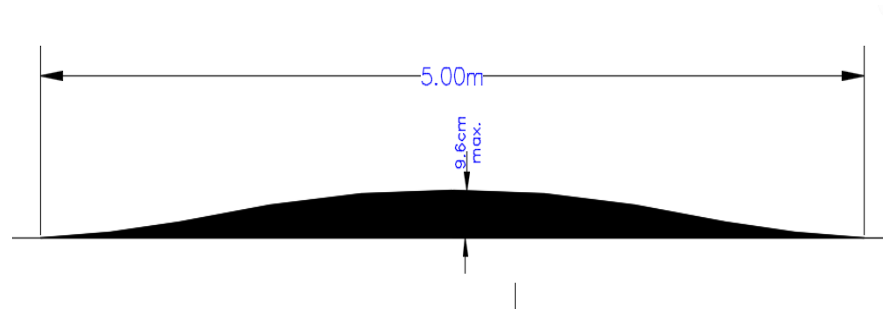


Figure 4- 7 the height in actual site at a distance

4.1.3 Road geometrics of Betel RA to keranyo RA

General description of Betel RA to keranyo RA

From the observation the geometrical design of selected road is straight road with construction of speed humps and rumble strip along the road. The road (i.e. Betel RA to keranyo RA) was dual carriage way and three lanes in each way (3.5m width per lane) and speed humps are found only on one direction. There for, only one direction is selected for this study. This road connected to the road from Betel RA to keranyo RA which starting from UTM and ADINDAN coordinate (466300.2932, 995099.7674) end on coordinate (467055.9246, 996571.2936). It is under drain

drainage system. And pedestrian walk way was 4.9m. In general, the road has been under DS1 ERA Geometric Design Manual-2002.

4.1.3.1 General geometric description of speed hump design and its characteristics of Betel RA to Kolfe keranyo RA

From the general observation it has eight speed humps and thirteen rumble strip in between the speed humps that used to alert the driver along the selected road (i.e. Betel RA to keranyo RA). For this study take one speed hump.

There is no any indicated speed limit along the selected road and also there is no any indicated sign to know whether there is speed hump ahead or not. During observation Bethel Round about to keranyo Round about road site actual measurement indicated that hump width 9.60 meter, length 7.4 meter and 100 millimeter height at the center and it is tapered humps (humps that are not completely curb-to-curb so the channel width on each side 200mm as shown the (Figure4-8) below. The hump has been located at a distance of 583meters from Bethel Round about.

Moreover, adequate road markings and signing was placed in advance of and on the hump that guide subsequent movements. Furthermore, there is installed road studs on hump also has make visible at night (Figure 4-9) below. The next road humps and rumble strip was located at a distance of 148 meter and 33 meter respectively from the first road hump. The actual dimension of the road hump on Bethel round about to keranyo round about during observation is shown the table 4-4 below.

Road hump on	Width(m)	length(m)	height(mm)
Bethel round about to keranyo round about	9.60	7.40	100

Table 4- 4 Dimension of hump on Bethel round about to keranyo round about

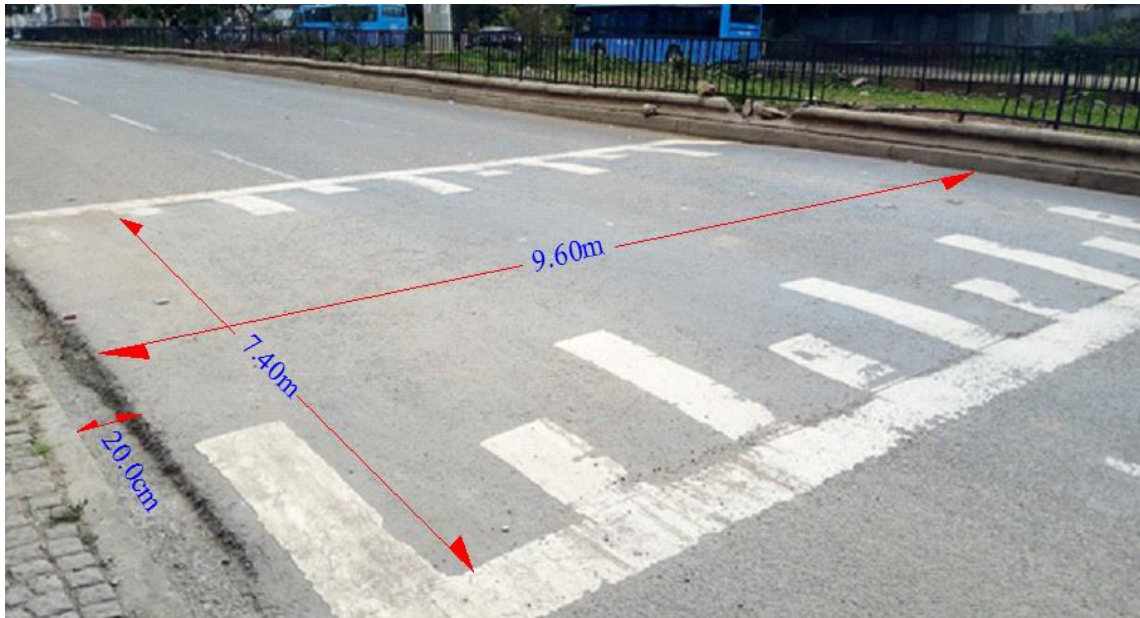


Figure 4- 8 Dimension on actual measurement

Source: photo takes on site



Figure 4- 9 Photo shows reflectors on hump

And the actual measurements on hump as shown on profile and picture below. 'From TRL' standard.

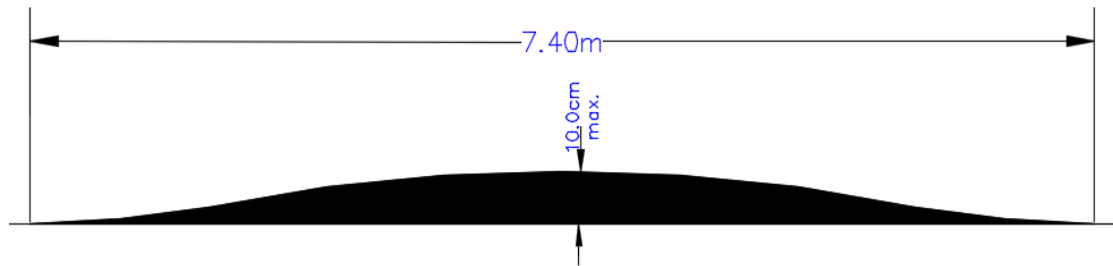


Figure 4- 10 Height and length of hump

4.1.4 Road geometrics of Ayer tena to Jemo Michel

General description of Ayer tena to Jemo Michel

From the observation the geometrical design of selected road is straight road with construction of speed humps and rumble strip along the road. The road (i.e. Ayer tena to Jemo Michel) was ring road having raised median two-way and three lanes in each way (3.5m width per lane) and speed humps are found on two directions. But, only one direction is selected for this study. It is under drain drainage system. And pedestrian walk way was 5m.

4.1.4.1 General geometric description of speed hump design and its characteristics

From the general observation it has one speed humps and one rumble strip before the speed humps that used to alert the driver along the selected road (i.e. Ayer tena to Jemo Michel). For this study take one speed hump.

The indicted speed limit along the selected road was 50 km/hr. And the warning sign also contains there is speed hump ahead as shown the Figure (4-11) below and the warning sign on this site placed at a distance of 70m from the speed hump.



Figure 4- 11 Speed Hump Warning Sign



Figure 4- 12 photo show not road marking

Source: photo takes on site

During observation Ayer tena to Jemo Michel road site actual measurement indicated that hump width 10.5 meter, length 10.8 meter and 100 millimeter height at the center and it is tapered humps (humps that are not completely curb-to-curb so the channel width on each side 200mm as shown the (Figure4-13) below.

Concerning on road markings, even if road marking in advance of road hump that guide subsequent movements there is no any road marking on a hump shown (Figure 4-13) above. But, there is installed road studs on hump also has make visible at night (Figure 4-14) below. There is ramble strip at a distance of 35m before speed hump. The actual dimension of the road hump on Ayer tena to Jemo Michel during observation are shown the Table 4-5 below.

Road hump on	Width(m)	length(m)	height(mm)
Ayer tena to Jemo Michel	10.5	10.8	100

Table 4- 5 Dimension of hump on Bethel round about to keranyo round about



Figure 4- 13 Dimension of speed hump

Source: photo takes on site



Figure 4- 14 Photo shows reflectors on hump

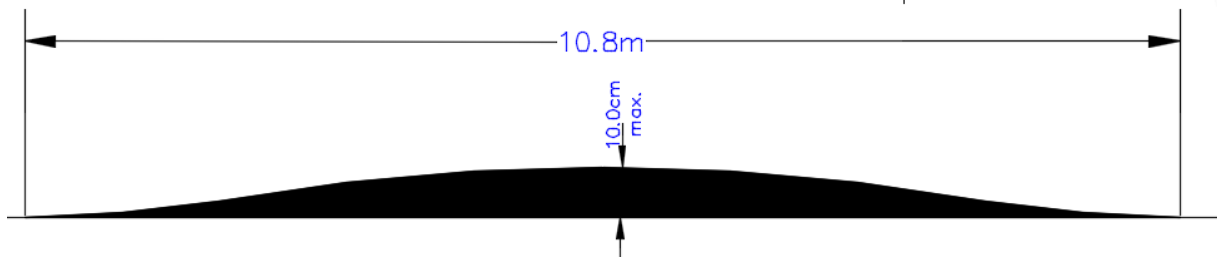


Figure 4- 15 Height and length of Hump of hump

4.1.5 Road geometrics of Kara to Wesson

General description of Wesson to Kara

From the observation the geometrical design of selected road is straight road with construction of speed humps along the road. Road (i.e. Kara to Wesson) was one way and three lanes having (3.5m width per lane). And pedestrian walk way was 4.5m.

4.1.5.1 General geometric description of speed hump design and its characteristics

From the general observation it has three speed humps and no rumble strip but yellow paint before speed hump that used to guide the driver along the selected road. For this study take one speed hump.

The indicted speed limit along the selected road was 30 km/hr. And the warning sign also contains there is speed hump ahead as shown the Figure (4-54) below and the warning sign on this site placed at a distance of 50m from the speed hump. The warning signs were either mounted on signposts or banded to existing utility poles



Figure 4- 16 Speed Hump Warning Sign

Source: photo takes on site

During observation Kara to Wesson road site actual measurement indicated that hump width 10 meter, length 7.4 meter and 100 millimeter height at the center and it is tapered humps (humps that are not completely curb-to-curb so the channel width on each side 200mm as shown the (Figure4-17) below.

Moreover, adequate road markings and signing was placed in advance of and on the hump that guide subsequent movements. Furthermore, there is installed road studs on hump also has make visible at night (Figure 4-18) below. The next speed hump was located at a distance of 180 meter

from the first road hump. The actual dimension of the road hump on Kara to Wesson during observations are shown the Table 4-6 below.

Road hump on	Width(m)	length(m)	height(mm)
Kara to Wesson	10	7.40	100

Table 4- 6 Dimension of hump on Bethel round about to keranyo round about



Figure 4- 17 Dimension on actual measurement



Figure 4- 18 Photo shows reflectors on hump

The actual measurement on hump as shown on profile and picture below.

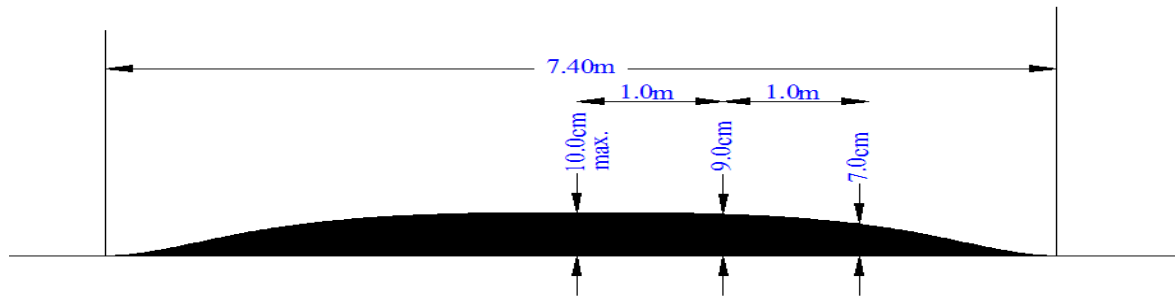


Figure 4- 19 Height of hump at a distance

4.1.6 Road geometrics of Bisrate Gebrel to Abo RA

General description of Bisrate Gebrel to Abo RA

From the observation the geometrical design of selected road is straight road with construction of speed humps and rumble strip along the road. The road (i.e. to Bisrate Gebrel to Abo RA) was dual carriage way having median and three lanes in each way (3.5m width per lane) and speed humps are found only on one direction. There for, only one direction is selected for this study. It is under drain drainage system. And pedestrian walk way was 4.8m. In general, the road has been under DS1 ERA Geometric Design Manual-2002.

4.1.6.1 General geometric description of speed hump design and its characteristics

From the general observation it has three speed humps and eight rumble strip that used to alert the driver along the selected road (i.e. Bisrate Gebrel to Abo RA). for this study take one speed hump.

The indicted speed limit along the selected road was 30 km/hr. And the warning sign also contains there is speed hump ahead as shown the Figure (4-20) below and the warning sign on this site placed at a distance of 90m from the speed hump

During observation Bisrate Gebrel to Abo Round about road site actual measurement indicated that hump width 10 meter, length 7.4 meter and 100 millimeter height at the center and it is

tapered humps (humps that are not completely curb-to-curb so the channel width on each side 200mm as shown the (Figure4-21) below.



Figure 4- 20 Speed Hump Warning Sign

Moreover, adequate road markings and signing was placed in advance of and on the hump that guide subsequent movements. Furthermore, there is installed road studs on hump also has make visible at night (Figure 4-22) below. The next road humps and rumble strip was located at a distance of 180 meter and 100 meter respectively from the first road hump. The actual dimensions of the road hump on Bisrate Gebrel to Abo round about during observation are shown the table 4-7 below.

Road hump on	Width(m)	length(m)	height(mm)
Bisrate Gebrel to Abo RA	10	7.40	100

Table 4- 7 Dimension of hump on Bisrate Gebrel to Abo RA



Figure 4- 21 Dimension on actual measurement

Source: photo takes on site



Figure 4- 22 Photo shows reflectors on hump

Source: photo takes on site

The actual measurements on hump are as shown on profile and picture below.

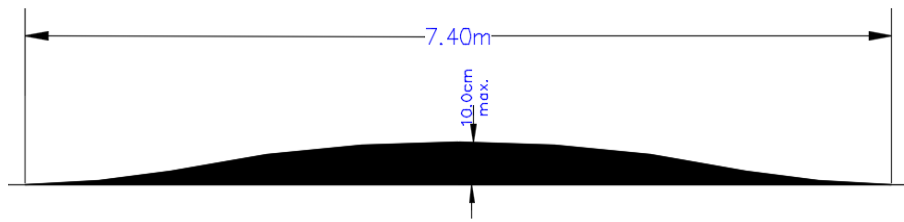


Figure 4- 23 Height and length of hump

4.1.7 Road geometrics of Anfo RA to Keranyo RA

General description of Anfo RA to Keranyo RA

From the observation the geometrical design of selected road is straight road with construction of speed humps and rumble strip along the road. The road (i.e. Anfo RA to Keranyo RA) was two way having median and two lanes in each way (3.5m width per lane) and speed humps are found only on one direction. There for, only one direction is selected for this study. It is under drain drainage system. And pedestrian walk way was 4.5m.

4.1.7.1 General geometric description of speed hump design and its characteristics

From the general observation it has three speed humps and eight rumble strip that used to alert the driver along the selected road (i.e. Bistrate Gebrel to Abo RA). for this study take one speed hump as shown (Figure 4-24) bellow.

There is no any indicated speed limit along the selected road and also there is no any indicated sign to know whether there is speed hump ahead or not.

Placement of the warning signs was left to the concerned body, but it was specified that the warning signs should be placed at least 100 feet (30.48m) in advance of the speed hump. The 100-foot (30.48m) distance meets the placement requirements of warning signs set forth by the 2000 MUTCD (FHWA, 2000). The warning signs were either mounted on sign posts or banded to existing utility poles.

During observation Anfo RA to Keranyo RA road actual measurement indicated that hump width 7 meter, length 7.4 meter and 100 millimeter height at the center and it is tapered humps (humps that are not completely curb-to-curb so the channel width on each side 200mm as shown the (Figure4-24) below.

But, adequate road markings and signing was placed on the hump, that guide subsequent movements. And also, there are not installed road studs on hump to make visible at night. The next speeds hump and rumble strip was located at a distance of 155 meter and 33 meter respectively from the road hump. The actual dimensions of the road hump on Anfo RA to Keranyo RA during observation are shown the table 4-8 below.

Road hump on	Width(m)	length(m)	height(mm)
Anfo RA to Keranyo RA	7	7.40	100

Table 4- 8 Dimension of hump on Anfo round about to Keranyo round about



Figure 4- 24 Dimension on actual measurement

Source: photo takes on site

The actual measurement on hump as shown on profile and picture below.

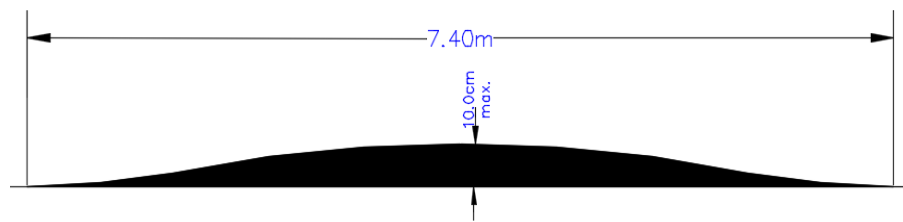


Figure 4- 25 Height of hump at a distance

Generally, the road hump should be design and built properly to minimize discomfort for those road users with appropriate speed. More over the design characteristics of road hump should follow guide line to reduce the degree of discomfort. The height of a road hump must not exceed 100 mm, and it is generally recommended that it does not exceed 75 mm regardless of the profile (Local Transport Note 01/07, London, 2007) and if it is Tapered humps (humps that are not completely curb-to-curb) should not generally have a channel greater than 200 mm (Local Transport Note 01/07, London, 2007).

In addition to this the spacing between properly designs Speed humps should be constructed in succession to be most effective. For local roads, speed humps are usually Constructed 150–250 yards (137.16-228.6 meter) apart. The lengths and heights of the humps determine the speed at which traffic will travel over them. Shorter lengths and greater heights slow vehicles considerably. (Ewing, 1999) . For round-top the recommended height is 100 mm and the length is 3.0 m, 4.0 m, 6.5 m and 9.5 m for use on roads where the desired speeds are 20 kph, 30 kph, 40 kph and 50 kph respectively. (TRL377,1998). And also, a slight change in the construction of road hump can have significant effects in terms of discomfort and it is therefore important that humps are built accordingly. [WRI standard]

It's well-known that there are different kinds of road hump profile such as sinusoidal, circular, modified circular and flat top hump. From measurement and observation, the hump found on the selected sites have modified circular hump because the initial jolt experienced when crossing a round-top hump can be lessened by 'feathering' the leading and trailing edges to give a smooth

transition between the road hump, feathering the leading edge of a round-top hump can reduce the discomfort ratings. Feathering can therefore be used to lower the discomfort caused by a round-top hump at a given speed. (TRL REPORT 377, 1998).

It was specified that the warning signs should be placed at least 100 feet (30.48m) in advance of the speed hump. The 100-foot(30.48m) distance meets the placement requirements of warning signs set forth by the 2000 MUTCD (FHWA, 2000). The warning signs were either mounted on signposts or banded to existing utility poles.

4.1.8 Spot speed analysis

The spot speed data was collected at Selected seven site having speed humps found in Addis Ababa, Ethiopia such as, Sidest kilo to Afincho ber, Balderas to Aware round about, Betel round about to Keranyo, Keranyo round about to Anfo, Ayertena to Jemo Michel, Kara to Wesson and Bisrate Gebrel to Abo round about. The spot speed data collection was carried out during week day. All this data was taken from 10:00 am. to 12:00 pm. as to avoid peak hour for traffic flow. This is because free flow speed of vehicle in actual situation when approaching and passing through the road hump can be obtained during off-peak hours. The weather during the collection was sunny.

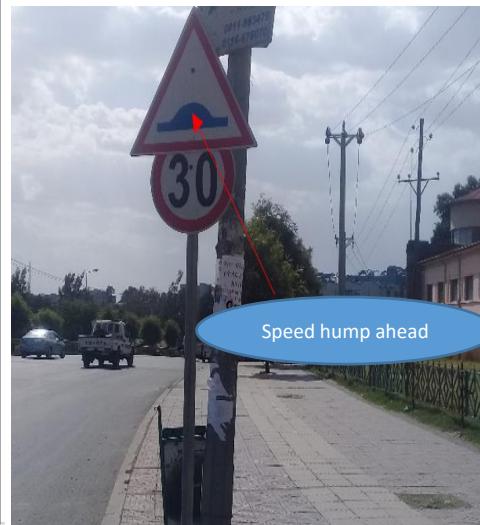
4.1.8.2 Spot speed analysis for Sidest kilo to Afincho ber

The spot speed data collected at Sidest kilo to Afincho ber hump were analyzed in this study

Table 4- 9 Spot speed data on Sidest kilo to Afincho ber road



No.	Speed [Km/hr.]			No.	Speed [Km/hr.]		
	50m before hump	50m after hump	At speed hump		50m before	50m after hump	At speed hump
1	39	34	23	26	44	34	17
2	37	32	15	27	36	23	10
3	40	36	22	28	45	39	12
4	27	27	23	29	41	33	16
5	41	31	20	30	39	25	18
6	46	35	11	31	41	41	16
7	49	37	14	32	37	25	19
8	39	32	16	33	38	35	13
9	28	33	14	34	53	22	22
10	45	29	18	35	37	27	12
11	36	34	16	36	43	24	14
12	36	39	21	37	48	35	21
13	38	31	15	38	40	31	23
14	38	31	14	39	45	32	22
15	37	37	21	40	37	36	23
16	39	24	16	41	36	23	18
17	40	31	15	42	41	30	13
18	37	35	14	43	40	30	10
19	44	33	15	44	43	28	26
20	37	32	13	45	40	35	17
21	41	31	14	46	37	38	11
22	46	29	12	47	50	22	13
23	36	32	19	48	44	24	10
24	43	29	12	49	43	36	25
25	37	32	14	50	49	30	9



No.	Speed [Km/hr.]			No.	Speed [Km/hr.]		
	50m before hump	50m after hump	At speed hump		50m before	50m after hump	At speed hump
51	29	41	22	76	30	32	19
52	32	38	13	77	40	34	11
53	33	34	22	78	36	39	12
54	32	35	23	79	34	32	14
55	36	33	19	80	36	26	17
56	41	26	13	81	32	40	16
57	44	37	14	82	33	26	19
58	34	31	15	83	48	32	23
59	31	32	16	84	32	41	21
60	40	34	18	85	38	27	15
61	31	32	17	86	43	42	12
62	29	35	21	87	35	23	21
63	29	31	15	88	40	31	22
64	33	29	14	89	32	40	24
65	33	38	23	90	32	36	22
66	32	35	18	91	28	40	20
67	34	32	17	92	35	32	16
68	35	35	13	93	38	32	12
69	33	33	15	94	29	27	24
70	39	42	13	95	40	34	18
71	27	29	13	96	38	39	13
72	37	39	14	97	51	37	14
73	41	33	21	98	41	29	12
74	31	31	12	99	43	37	25
75	39	34	14	100	49	31	11

As shown the table above, (Table 4-3) the lowest and the highest speed before approaching speed hump that is at distance of 50 meter was 27Km/hr. and 53Km/hr. respectively. it reduced to 9km/hr. and 26km/hr. while passing the speed hump respectively. That shows the average speed reduced by 56%. Whereas, the highest and the lowest speed at a distance of 50m after approaching the road hump was 42 km/hr. and 22Km/hr. respectively. That shows the average speed increases by 45% after passing speed hump.

The max, min and percent variation for each location are summarized on the following table (Table 4-10), spot speed data collected for the rest site refer on **Appendix C**:

street	Before speed hump		on speed Hump		After speed Hump		Speed reduced on hump (%)
	max	min	max	min	max	min	
Sidest killo to Afinch ber	53	27	26	9	42	22	56
Betel RA to keranyo	55	24	27	9	43	17	54.45
Ayer tena to jemo Michel	66	28	29	9	52	26	40.42
Kara to wossen	53	21	27	10	46	22	50
Bisrate Gebrel to Abo RA	56	21	27	10	45	24	52
Anfo RA to Keranyo RA	51	23	24	10	44	20	54
Aware Ra to balderas cond.	52	21	22	9	45	21	57.5

Table 4- 10 Summery of max speed, min speed and percent variation for each location

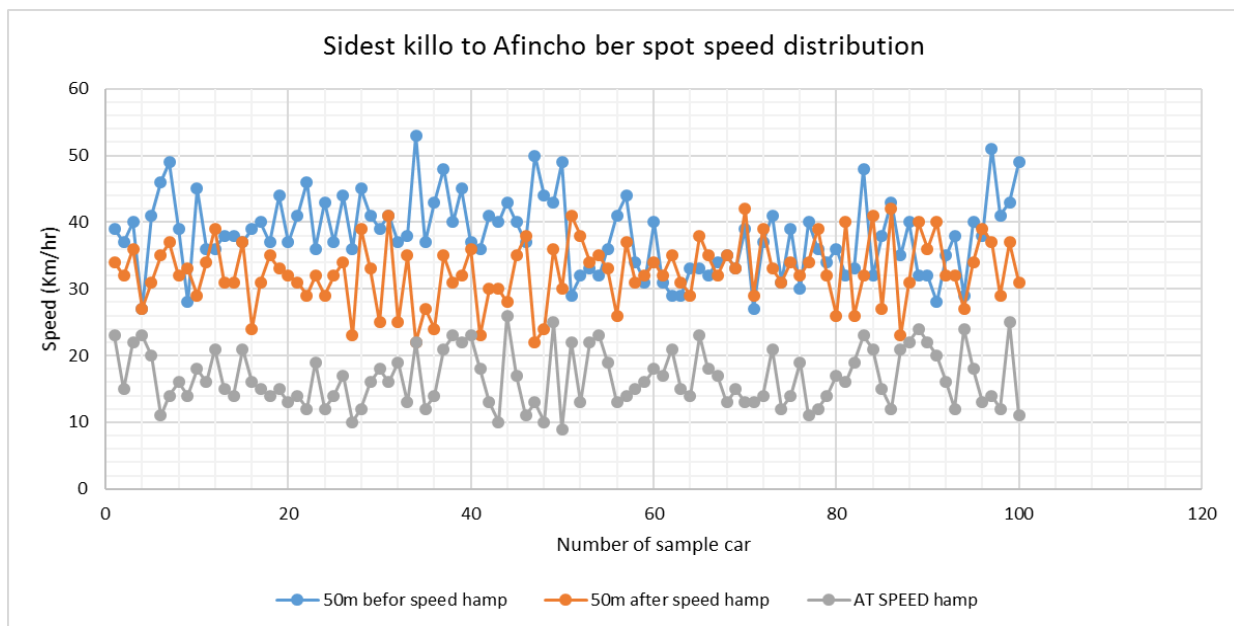


Figure 4- 26 Distribution of Spot Speed vs number of vehicle at three locations

From the finding, as shown the figure above, most of driver drove above the posted speed limit (i.e. 30Km/hr.) before speed hump at a distance of 50m. That is about 92 cars out of the sample taken (i.e.92%). On the other hand, at 50m after speed hump there were 76 cars (i.e.76%) speeding above the posted speed limit (i.e.30Km/hr.). But the highest and the lowest speed at a hump was 26Km/hr. and 9km/hr. respectively. That shows all the driver force to drive with in the posted speed limit.

From the Distribution of Spot Speed vs number of vehicle at three locations graph for the rest selected site identify that before and after 50m from the speed hump or from ramble strip above (half) 50 % of car travel above the posted speed limit. But almost all car travel below the posted speed limit on speed hump. Figure of Distribution of Spot Speed vs number of vehicle at three locations graph for the rest site found on Appendix D

4.1.8.3 Statistical Analysis of spot Speed before, After and on speed Humps

To determine the characteristics of speed from the collected data first determine number of classes that is, the number of velocity ranges into which the data are to be fitted. One technique that can be used to determine the number of classes is first determine the range for a class size of 8 and then for a class size of 20. Finding the difference between the maximum and minimum speeds in the data and dividing this number first by 8 and then by 20 gives the maximum and minimum ranges in each class. A convenient range for each class is then selected and the number of classes determined. Usually the mid value of each class range is taken as the speed value for that class. (Garber and Hoel, 2009). To calculate median of range of classes use the following equation

$$x = \frac{V_{\max} - V_{\min}}{8} \dots\dots\dots \text{Eq.1}$$

$$y = \frac{V_{\max} - V_{\min}}{20} \dots\dots\dots \text{Eq.2}$$

$$U_i = \frac{x+y}{2} \dots\dots\dots \text{Eq.3}$$

For Sidest kilo to Afincho ber road the speeds range before approaching the speed hump from 53km/hr. to 27Km/hr. giving a speed range of 26. For eight classes, the range per class is 3.25; for 20 classes, the range per class is 1.3. take the average it comes to 2.27. Therefore, it is convenient to choose a range of 2 per class which will give 9 classes. As shown the table below.



From the analysis: table, frequency histograms and cumulative frequency distribution graphs are generating for each place; before speed hump, after speed hump and on speed hump as shown below.

Table 4- 11 frequency distribution table for Sidest kilo to Afincho ber road spot speed study before approaching the speed hump

speed class(Km/h)	class mid value(Ui)	class frequency (number observation)	fiui	percentage of observation in a class	cummlative percentage observation in aclass	fi(ui-u)2	mean speed(u)	$\sqrt{\sum fi(ui-u)^2/n-1}$
27-29	28	8	224	8.00	8.00	808.02	38.05	5.7
30-32	31	11	341	11.00	19.00	628.69	38.56	
33-35	34	11	374	11.00	30.00	228.73	38.56	
36-38	37	24	888	24.00	54.00	58.41	38.56	
39-41	40	23	920	23.00	77.00	47.69	38.56	
42-44	43	10	430	10.00	87.00	197.14	38.56	
45-47	46	5	230	5.00	92.00	276.77	38.56	
48-50	49	6	294	6.00	98.00	653.96	38.56	
51-53	52	2	104	2.00	100.00	361.27	38.56	
		100	3805			3260.67		

sidist killo RA to Afincho ber befor SH

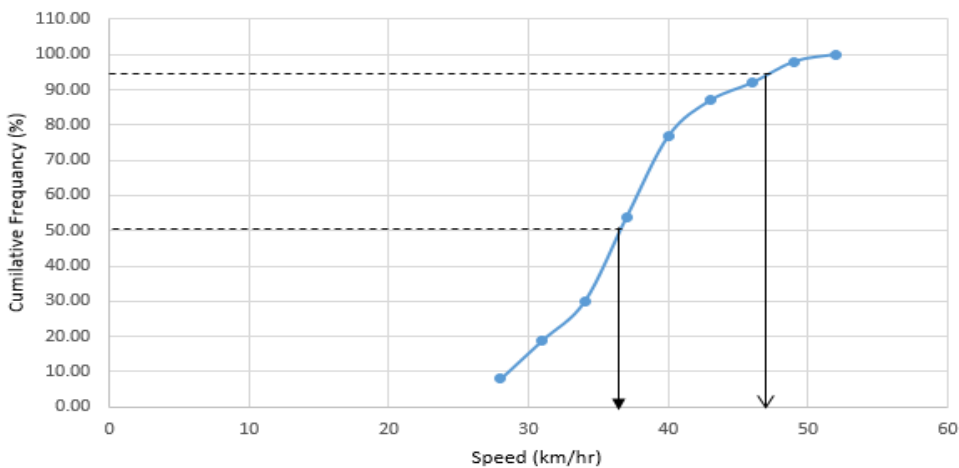


Figure 4- 27 Cumulative frequency curve with 85th & 50th level marked by dotted lines before hump

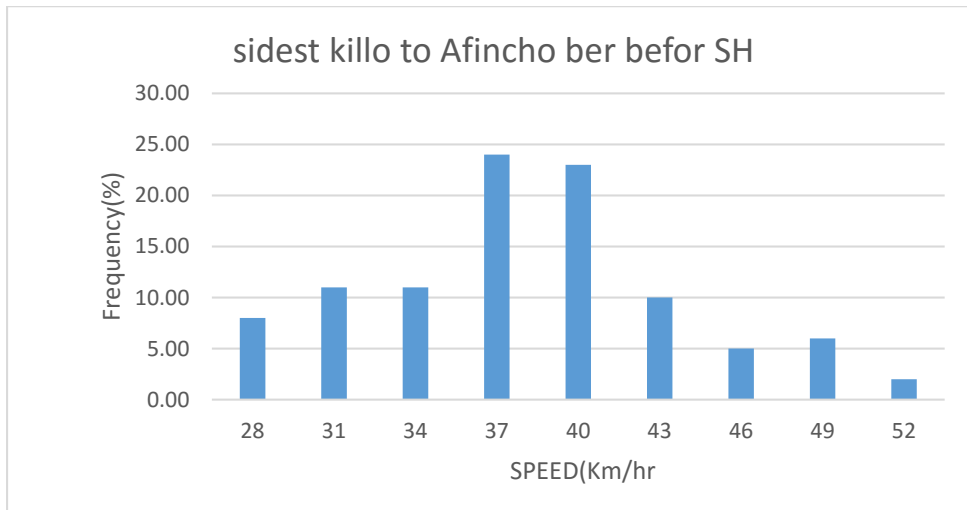


Figure 4- 28 Frequency histogram before speed hump

The spot speed characteristics such as mean, median, modal and 85th percentile speed before approaching the speed hump are calculated and obtain from the above graph and table. The median speed is obtained from the cumulative frequency distribution curve (Figure 4-8) as 37Km/hr. (i.e. the 50th-percentile speed). The mode or modal speed is obtained from the frequency histogram as 37Km/hr. (Figure 4-9). 85th-percentile speed is obtained from the cumulative frequency distribution curve as 46Km/hr. (Figure 4-8). This shows most of the driver drove above the speed limit before approaching the speed hump on this road. the mean speed before speed hump computed using the following equation

$$u = \frac{\sum f_i x_i}{\sum f_i} \dots\dots\dots \text{Eq.}$$

$$=38.05\text{Km/hr.}$$

From the statistical analysis: tables, cumulative frequency distribution curve and frequency histograms are generating **before approaching the speed hump**. For sadist kilo to Afincho ber has see-through above. For the rest site tables, cumulative frequency distribution curve and frequency histograms can be seen in Appendix E, Statistical Analysis of spot Speed before SH for each location summarized on the following table (Table 4-12),



Table 4- 12 Summarized statical analysis of spot speed before speed hump

street	Mean speed(Km/hr.)	Modal speed(Km/hr.)	Median(Km/hr.)	85th percentile
Betel RA to keranyo	40.18	43	39	45
Ayer tena to jemo Michel	45.72	46	42	52
Kara to wossen	37.15	40	38	43
Bisrate Gebrel to Abo RA	41.3	42	40	50
Anfo RA to Keranyo RA	36.3	49	38	41
Aware Ra to balderas condi	36.67	43	37	42

From this BSH on all site the 85th percentile speed above the posted speed limit

Table 4- 13 Frequency distribution table for Sidest kilo to Afincho ber road spot speed study on speed hump

speed class(Km/h	class mid value(Ui)	class frequency (number observation	fiui	percentage of observation in a	cummlativepercentag e observation in	fi(ui-u)2	mean speed(u)	$\sqrt{\sum fi(ui-u)^2/n-1}$
8-9.5	9	1	9	1	1	66.59	17.16	4.20
10-11.5	11	7	77	7	8	265.62	17.16	
12-13.5	13	19	247	19	27	328.81	17.16	
14-15.5	15	21	315	21	48	97.98	17.16	
16-17.5	17	13	221	13	61	0.33	17.16	
18-19.5	19	11	209	11	72	37.24	17.16	
20-21.5	21	9	189	9	81	132.71	17.16	
22-23.5	23	14	322	14	95	477.48	17.16	
24-25.5	25	4	100	4	99	245.86	17.16	
26-27.5	27	1	27	1	100	96.83	17.16	
		100	1716	100		1749.44		

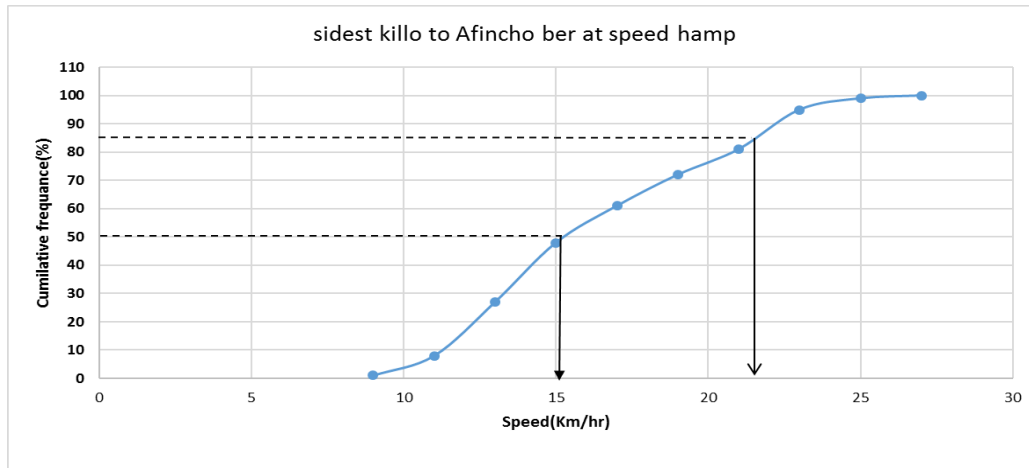


Figure 4- 29 Cumulative frequency curve with 85th & 50th level marked by dotted lines on speed hump.

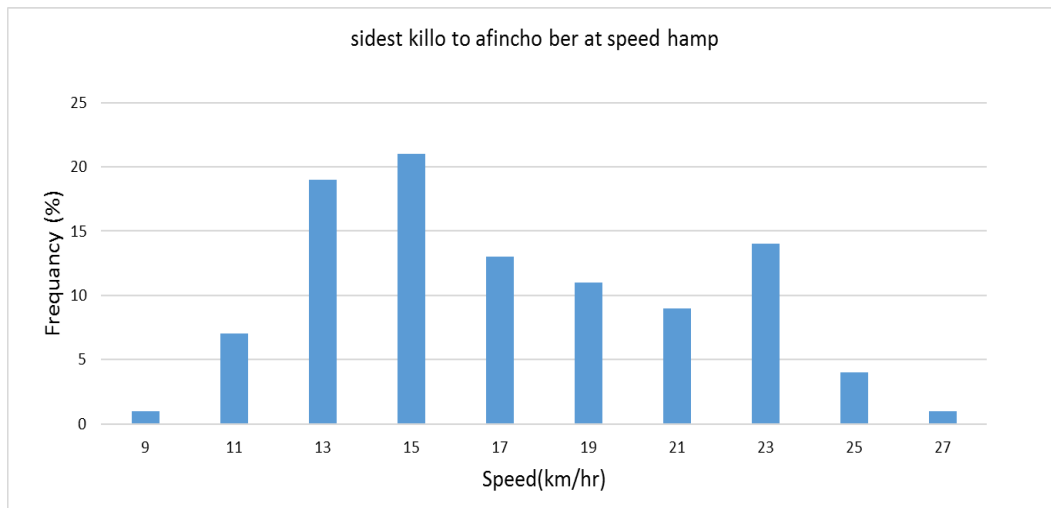


Figure 4- 30 Frequency histogram on hump

From the above graph the modal speed and the mean speed at the speed hump was 15km/hr. and 17.16km/hr. respectively. The average speed of the cars before approaching the hump decreases from 38.05 km/hr. to 17.16km/hr. at the hump. More over the 85th percentile speed reduces from 46Km/hr. to 22Km/hr. at speed hump.

From the statistical analysis: tables, cumulative frequency distribution curve and frequency histograms are generating on the speed hump. For sadist kilo to Afincho ber has revealing above. The rest tables, cumulative frequency distribution curve and frequency histograms are can be

seen in Appendix F, Statistical Analysis of spot Speed on SH for each location summarized on the following table,

Table 4- 14 summarized Statistical Analysis of spot Speed on SH for each location

street	Mean speed(Km/hr)	Modal speed(Km/hr)	Median(Km/hr)	85th percentile
Betel RA to keranyo	19	16	16	24
Ayer tena to jemo Michel	19.3	19	18	24
Kara to wossen	18	17	17	23
Bisrate Gebrel to Abo RA	17.8	17	16	21
Anfo RA to Keranyo RA	17.2	17	16	21
Aware Ra to balderas condi	17.95	13	17	23

Table 4- 15 Frequency distribution table for Sidest kilo to Afincho ber road spot speed study after speed hump

speed class(Km/h)	class mid value(U _i)	class frequency (number observation in a class;f _i)	f _{ii}	percentage of observation in a class	cummlativepercentage observation in aclass	f _i (u _i -u) ²	mean speed(u)	$\sqrt{\sum f_i(u_i-u)^2/n-1}$
22-23.9	23	5	115	5	5	498.002	32.98	4.85
24-25.9	25	5	125	5	10	318.402	32.98	
26-27.9	27	7	189	7	17	250.3228	32.98	
28-29.9	29	7	203	7	24	110.8828	32.98	
30-31.9	31	14	434	14	38	54.8856	32.98	
32-33.9	33	20	660	20	58	0.008	32.98	
34-35.9	35	17	595	17	75	69.3668	32.98	
36-37.9	37	9	333	9	84	145.4436	32.98	
38-39.9	39	8	312	8	92	289.9232	32.98	
40-41.9	41	6	246	6	98	385.9224	32.98	
42-43.9	43	2	86	2	100	200.8008	32.98	
		100	3298			2323.96		



Figure 4- 31 Cumulative frequency curve with 85th & 50th level marked by dotted lines after speed hump

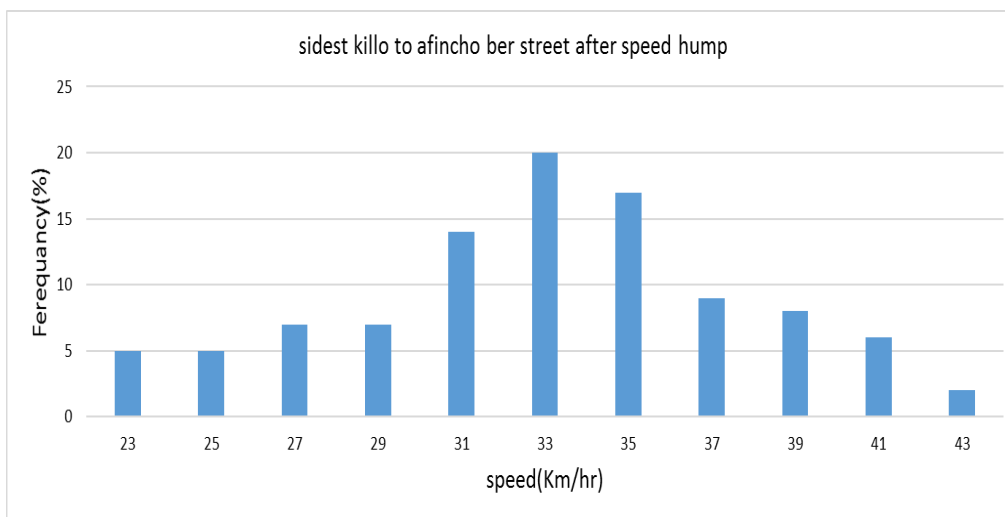


Figure 4- 32 Frequency histogram after speed hump

From the above graph the modal speed and the mean speed after passing the speed hump was 33km/hr. and 32.98km/hr. respectively. The average speed of the cars after passing the speed hump increase from 17.16 km/hr. to 32.98km/hr. More over the 85th percentile speed after passing the first speed hump that means in between the speed hump 37Km/hr.

From the statistical analysis: tables, cumulative frequency distribution curve and frequency histograms are generating after the speed hump. For sadist kilo to Afincho ber has revealing above. The rest tables, cumulative frequency distribution curve and frequency histograms are can

be seen in Appendix G, Statistical Analysis of spot Speed after SH for each location summarized on the following table,

Table 4- 16 summary of Statistical Analysis of spot Speed after SH for each location

street	Mean speed(Km/hr.)	Modal speed(Km/hr.)	Median(Km/hr.)	85th percentile
Betel RA to keranyo	24.67	24	24.67	26
Ayer tena to jemo Michel	37.83	39	37	43
Kara to wossen	30.88	31	31	35
Bisrate Gebrel to Abo RA	35.3	40	34	39
Anfo RA to Keranyo RA	33	36	33	39
Aware Ra to balderas condi	30.78	31	30	34

4.1.8.4 Statistical Analysis of the differences in the average speed of the vehicles before and on Humps

T-tests were done to test whether the average speed on hump and average speed before the humps have significantly difference. Table (4-7) shows the result of the paired samples t-tests on all site.

Table 4- 17 t-test result (SPSS output) for average speeds before 50m and on a hump

Street name	Pair	Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
					Lower	Upper			
Sidest killo - Afincho ber	Before hump - On hump	22.00	7.44	1.62	18.61	25.39	13.560	20	0.0000
Aware RA - Balderas cond.	Before hump - On hump	17.14	9.39	2.05	12.87	21.42	8.368	20	0.0000
Betel RA - Kolfe keranyo	Before hump - On hump	21.38	9.56	2.08	17.03	25.73	10.260	20	0.0000
Ayer tena - Jemo michel	Before hump - On hump	17.57	10.14	2.21	12.96	22.19	7.943	20	0.0000
Kara - Wesson	Before hump - On hump	22.00	7.44	1.62	18.61	25.39	13.560	20	0.0000
Bisrate gebrel - Abo RA	Before hump - On hump	26.71	7.38	1.61	23.35	30.08	16.580	20	0.0000
Anfo RA - Keranyo RA	Before hump - On hump	17.14	9.39	2.05	12.87	21.42	8.368	20	0.0000

In this analysis to be significant there are three ways to know whether it is significant or not. The first one is calculated $t_{\text{value}} > t_{\text{critical}} (t_{\alpha} (n-1))$. From the finding as shown the above table the calculated t-value which is higher than the critical t-value at 20 degree of freedom and 0.05 significance level. Second the p-value < 0.05 which is P-value = 0.0000 which is less than 0.05 and

also the confidence interval does not contain zero. From the statistical analysis, it can be concluded that there are significant differences in average speed on the speed hump and 50m before speed hump at 95% confidence interval. Thus, the speed hump along the selected site has been effective by controlled the drivers' behavior in reducing speed of vehicles.

4.2. Traffic Crash analysis of the Seven selected area

The traffic Crash data was collected at seven selected areas at different sub city in Addis Ababa, Ethiopia such as, Gulele sub city; For street Sidest kilo round about to Afincho ber, Yeka sub city; for Aware RA to Balderas Condominium, Wesson to Kara, Kolfe keranyo sub city; for Betel RA to Keranyo RA, Keranyo RA to Anfo and Ayer tena to Jemo Michel and Nifas silk sub city; for Bistrate Gebrel to Abo RA. The traffic Crash data that regard the selected road was collected from the above sub city before and after the construction of speed hump from 2009 EC to 2012EC for each sub city. The following tables shows collected traffic crash data.

Table 4- 18 Traffic Crash on Gulele sub city from Sidest kilo to Afincho ber

Street	Construction date	Study period (month) before SH construction	Number of traffic Crash before SH construction			Number traffic Crash Before construction	Study period (month) After SH construction	Number of traffic Crash after SH construction			Number traffic Crash After SH construction
			sligt	sever	Fatal			sligt	sever	Fatal	
Sidest kilo to Afincho ber	April 2010 EC	May-09	7			7	May-10	3	1		4
		Jun-09	5	1		6	Jun-10	4			4
		Jul-09	9			9	Jul-10	4	1		5
		Aug-09	6	2		8	Aug-10	5			5
		Sep-10	5	1		6	Sep-11	4			4
		Oct-10	8	1		9	Oct-11	7	1		8
		Nov-10	10			10	Nov-11	3			3
		Dec-10	3	2		5	Dec-11	7			7
		Jan-10	6			6	Jan-12	6	1		7
		Feb-10	7	1		8	Feb-12	3			3

Table 4- 19 Traffic Crash Kolfe Keranyo sub city on Betel RA to keranyo RA

Street	Construction date	Study period (month) before SH construction	Number of traffic Crash before SH construction			Number traffic Crash Before construction	Study period (month) After SH construction	Number of traffic Crash after SH construction			Number traffic Crash After SH construction
			sligt	sevier	Fatal			sligt	sevier	Fatal	
Betel to Keranyo	April 2010 EC	Jun-09	8			8	Jun-10	4	2		6
		Jul-09	5	2		7	Jul-10	6	1		7
		Aug-09	4	1		5	Aug-10	6			6
		Sep-09	8	1		9	Sep-11	5	1		6
		Oct-09	6	1		7	Oct-11	4			4
		Nov-10	5	1		6	Nov-11	3	1		4
		Dec-10	6	1		7	Dec-11	3			3
		Jan-10	3	2	1	6	Jan-11	3			3
Feb-10	3	1		4	Feb-11	2	1		3		

Table 4- 20 Traffic Crash on Yeka sub city Aware RA to Balderas condominium

Street	Construction date	Study period (month) before SH construction	Number of traffic Crash before SH construction			Number traffic Crash Before construction	Study period (month) After SH construction	Number of traffic Crash after SH construction			Number traffic Crash After SH construction
			sligt	sevier	Fatal			sligt	sevier	Fatal	
Aware to Balderas	April 2010 EC	Feb-09	5	1		6	May-10	2	1		3
		Mar-09	8			8	Jun-10	4			4
		Apr-09	5			5	Jul-10	4	1		5
		May-09	10	2		12	Aug-10	4			4
		Jun-09	6	1	1	8	Sep-11	5			5
		Jul-09	8	2		10	Oct-11	3	1		4
		Aug-09	10			10	Nov-11	6	1		7
		Sep-10	6			6	Dec-11	4	1		5
		Oct-10	6	1		7	Jan-11	4	2		6
		Nov-10	7	2		9	Feb-11	3	1		4
		Dec-10	6	1		7	Mar-11	2	1		3
		Jan-10	2	2		4	Apr-11	5			5
		Feb-10	8			8	May-11	2	2		4
Mar-10	8	1		9	Jun-11	4	1		5		

Table 4- 21 Traffic Crash on Kolfe keranyo sub city Anfo RA to Keranyo RA

Street	Construction date	Study period (month) before SH construction	Number of traffic Crash before SH construction			Number traffic Crash Before construction	Study period (month) After SH construction	Number of traffic Crash after SH construction			Number traffic Crash After SH construction
			sligt	sevier	Fatal			sligt	sevier	Fatal	
Anfo to Keranyo	April 2010 EC	May-09	3	1	1	5	Jun-10	2			2
		Jun-09	3	1		4	Jul-10	1			1
		Jul-09	6			6	Aug-10	4	1		5
		Aug-09	5			5	Sep-11	2			2
		Sep-10	4			4	Oct-11	2			2
		Oct-10	6			6	Nov-11	4			4
		Nov-10	4	1		5	Dec-11	2	1		3
		Dec-10	3			3	Jan-12	3			3
		Jan-10	4			4	Feb-12	2			2
		Feb-10	6			6	Mar-12	3	1		4
		Mar-10	4			4	Apr-12	4			4
		Apr-10	2	1		3	May-12	3			3

Table 4- 22 Nifas silk sub city; Bisrate Gebrel to Abo RA to

Street	Construction date	Study period (month) before SH construction	Number of traffic Crash before SH construction			Number traffic Crash Before construction	Study period (month) After SH construction	Number of traffic Crash after SH construction			Number traffic Crash After SH construction
			sligt	sevier	Fatal			sligt	sevier	Fatal	
Bisrate gebrel to Abo RA	April 2010 EC	May-09	9			9	Jun-10	4			4
		Jun-09	7			7	Jul-10	3			3
		Jul-09	6	1		7	Aug-10	4	1		5
		Aug-09	9			9	Sep-11	4			4
		Sep-10	8			8	Oct-11	5			5
		Oct-10	6			6	Nov-11	3	1		4
		Nov-10	7			7	Dec-11	4			4
		Dec-10	4	2		6	Jan-12	3			3
		Jan-10	5			5	Feb-12	2			2
		Feb-10	6			6	Mar-12	3			3
		Mar-10	3	1		4	Apr-12	4			4
		Apr-10	3			3	May-12	3			3

Table 4- 23 Traffic Crash on Yeka sub city Kara to wesson

Street	Construction date	Study period (month) before SH construction	Number of traffic Crash before SH construction			Number traffic Crash Before construction	Study period (month) After SH construction	Number of traffic Crash after SH construction			Number traffic Crash After SH construction
			slight	sevier	Fatal			slight	sevier	Fatal	
Kara to Wossen	April 2010 EC	Sep-10	19			19	Nov-11	5			5
		Oct-10	11			11	Dec-11	7			7
		Nov-10	14	1		15	Jan-11	6	1		7
		Dec-10	18			18	Feb-11	7			7
		Jan-10	15			15	Mar-11	6			6
		Feb-10	7	1		8	Apr-11	13			13
		Mar-10	21	1		22	May-11	11	1		12
		Apr-10	13			13	Jun-11	7			7
		May-10	11		1	12	Jul-11	8			8
		Jun-10	11	1		12	Aug-11	11			11
		Jul-10	21	1		22	Sep-12	8		1	9
		Aug-10	9			9	Oct-12	8			8
Sep-10	13			1	14	Nov-12	10			10	

Table 4- 24 Traffic Crash on Keranyo sub city from Ayer tena to Jemo Michel

Street	Construction date	Study period (month) before SH construction	Number of traffic Crash before SH construction			Number traffic Crash Before construct	Study period (month) After SH construction	Number of traffic Crash after SH construction			Number traffic Crash After SH constructi
			slight	sevier	Fatal			slight	sevier	Fatal	
Ayer tena to Jemo	April 2010 EC	Feb-10	6	1	1	8	Apr-11	10			10
		Mar-10	9	1		10	May-11	5	3		8
		Apr-10	5	1		6	Jun-11	8			8
		May-10	24	3	1	27	Jul-11	9			9
		Jun-10	15	3		18	Aug-11	8			8
		Jul-10	12	2		14	Sep-12	5	1		6
		Aug-10	14	2		16	Oct-12	4			4
		Sep-11	5	1		6	Nov-12	4			4
		Oct-11	18	4		22	Dec-12	3	1		4
		Nov-11	13	2		15	Jan-12	3			3
		Dec-11	10			10	Feb-12	3			3
		Jan-11	19			19	Mar-12	5			5
		Feb-11	11				11	Apr-12	2	1	

Addis Ababa traffic police Commission and the selected site sub cities reported the number of traffic Crash which occurred on street Gulele sub city; Sidest kilo round about to Afincho ber, Yeka sub city; Aware RA to Balderas Condominium, Wesson to Kara, keranyo sub city; Betel RA to



Keranyo RA, Keranyo RA to Anfo and Ayer tena to Jemo Michel and Nifas silk sub city; Abo RA to Bisrate Gebrel. Before and after the speed hump constructions.

4.2.1 The percentage of traffic Crash reduction after the construction of speed hump

The percentage of traffic Crash reduction after the construction of speed humps are express as follows

- Before ten months the construction of speed humps, there were 74 reported traffic Crash that is 66 reported slight, 8 reported Sever and no fatal reported on Sidest kilo to Afincho ber road during the study period; ten months after the construction of speed hump, there were 50 reported Crash on this road that is 46 reported slight, 4 reported Sever and there is not reported fatal crash. There are certain methods to reduce traffic crash but the contribution of speed hump is high to reduce traffic crash that is during the study period the traffic crash reduced by 52 %.
- Before nine months the construction of speed humps, there were 59 reported traffic Crash that is 48 slight, 10 Sever and 1 fatal on Betel RA to keranyo RA road, nine months after the construction of speed hump, there were 42 reported traffic Crash on this road that is 36 slight, 6 Sever and 0 fatal report during the study period. There are certain methods to reduce traffic crash but the contribution of speed hump is high to reduce traffic crash that is during the study period the traffic crash reduced by 28.81% after the construction of speed hump.
- Before one year the construction of speed humps, there were 109 reported traffic Crash that is 95 slight, 13 Sever and 1 fatal on Aware to Balderas condominium road, one year after the construction, there were 64 reported traffic Crash that is 52 slight, 12 Sever and 0 fatal report during the study period on this road during the study period. There are certain methods to reduce traffic crash but the contribution of speed hump is high to reduce traffic crash that is during the study period the traffic crash reduced by 41.3%.
- Before thirteen months the construction of speed humps, there were 182 reported traffic Crash that is 160 slight, 20 Sever and 2 fatal on Ayer tena to Jemo Michel road during the study period, thirteen months after the construction, there were 75 reported traffic Crash



that is 69 slight, 6 Sever and 0 fatal on this road. There are certain methods to reduce traffic crash but the contribution of speed hump is significance during the study period the traffic crash reduced by 58.79%.

- Before twelve months the construction of speed humps, there were 55 reported traffic Crash that is 50 slight, 4 Sever and 1 fatal on Anfo RA to Keranyo RA road during the study period, twelve months after the construction, there were 35 reported Crash on this road that is 32 slight, 3 Sever and 0 fatal. There are certain methods to reduce traffic crash but the main contribution is speed hump during the study period the traffic crash reduced by 36.36 %.
- Before twelve months the construction of speed humps, there were 77 reported traffic Crash that is 73 reported slight, 4 reported Sever and 0 reported fatal on Bistrate Gebrel to Abo RA road, twelve months after the construction, there were 44 reported Crash on this road that is 42 slight, 2 Sever and 0 fatal during the study period. There are certain methods to reduce traffic crash but the main contribution is speed hump during the study period the traffic crash reduced by 42.8 %.
- Before thirteen months the construction of speed humps, there were 190 reported traffic Crash that is 183 slight, 5 Sever and 2 fatal on Wesson to Kara road, twelve months after the construction, there were 110 reported Crash that is 107 slight, 2 Sever and 1 fatal on this road. There are certain methods to reduce traffic crash but the main contribution is speed hump during the study period the traffic crash reduced by 42 %.
- From this traffic Crash results the entire selected site shows reduced traffic Crash after the construction of speed humps that shows even if other factor to reduce traffic crash the contribution of speed hump in reducing traffic crush is high.

4.2.2. Statistical Analysis of the difference of mean of the traffic Crash data before and after speed hump construction

T-tests were done to test whether mean of the traffic Crash data before and after speed hump construction have significantly difference. The following Table shows the result of statical test on Sidest kilo to Afincho ber road.



*Paired sample test***Table 4- 25 t-test result for traffic Crash data before and after speed hump construction on Sidest kilo to Afincho ber road**

		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence				
					Lower	Upper			
sidet kilo to Afincho ber	Befor -after speedhump installation	2.40	2.67	0.85	0.49	4.31	2.84	9	.019

In this analysis to be significant there are three ways to know whether it is significant or not. The first one is calculated $t_{\text{value}} > t_{\text{critical}} (t_{\alpha} (n-1))$. From the finding as shown the above result the calculated t-value (i.e.2.837) which is higher than the critical t-value at 9 degree of freedom and 0.05 significance level that is 1.833. Second the p-value < 0.05 which is P-value = 0.019 which is less than 0.05. and also the confidence interval does not contain zero. From the statistical analysis, it can confirm that there are differences in mean of traffic Crash data before and after the construction of speed hump at 95% confidence interval. There are certain methods to reduce traffic crash but the contribution of the speed hump along Sidest kilo to Afincho ber is high by controlled the drivers' behavior in reducing traffic crash.

Table 4- 26 t-test result for traffic Crash data before and after speed hump construction on Betel RA to keranyo RA road

Paired Samples Test									
		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
					Lower	Upper			
Pair 1	Befor -after speedhump installation	3.11	1.62	0.54	1.87	4.35	5.78	8	.000

In this analysis to be significant there are three ways to know whether it is significant or not. The first one is calculated $t_{\text{value}} > t_{\text{critical}} (t_{\alpha} (n-1))$. From the finding as shown table 4-53 the above result the calculated t-value (i.e.5.78) which is higher than the critical t-value at 9 degrees of freedom and 0.05 significance levels that is 1.86. Second the p-value < 0.05 which is P-value = 0.000

which is less than 0.05 and also the confidence interval does not contain zero. From the statistical analysis, it can confirm that there are differences in mean of traffic Crash data before and after the construction of speed hump at 95% confidence interval. There are certain methods to reduce traffic crash but the contribution of the speed hump along Betel RA to Keranyo RA is high by controlled the drivers' behavior in reducing traffic crash.

Table 4- 27 t-test result for traffic Crash data before and after speed hump construction on Aware RA to Balderas condominium

Paired Samples Test									
Aware RA to Balderas condominium		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
					Lower	Upper			
Pair 1	Befor -after	3.21	2.39	0.64	1.83	4.60	5.03	13	.000

In this analysis to be significant there are three ways to know whether it is significant or not. The first one is calculated $t_{\text{value}} > t_{\text{critical}} (t_{\alpha} (n-1))$. From the finding as shown the above result the calculated t-value (i.e.5.029) which is higher than the critical t-value at 13 degrees of freedom and 0.05 significance levels that is 1.771. Second the p-value < 0.05 which is P-value = 0.000 which is less than 0.05 and also the confidence interval does not contain zero. From the statistical analysis, it can be confirmed that there are differences in mean of traffic Crash data before and after the construction of speed hump at 95% confidence interval. There are certain methods to reduce traffic crash but the contribution of the speed hump along Aware RA to Balderas condominium is high by controlled the drivers' behavior in reducing traffic crash.

Table 4- 28 t-test result for traffic Crash data before and after speed hump construction on Anfo RA to Keranyo RA road

Paired Samples Test									
AnfoRA to Keranyo RA		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
					Lower	Upper			
Pair 1	Befre - After	1.66667	1.15470	.33333	.93300	2.40033	5.000	11	.000



In this analysis to be significant there are three ways to know whether it is significant or not. The first one is calculated $t_{\text{value}} > t_{\text{critical}} (t \alpha (n-1))$. From the finding as shown the above result the calculated t-value (i.e.5.00) which is higher than the critical t-value at 11 degrees of freedom and 0.05 significance levels that is 1.796. Second the p-value < 0.05 which is P-value = 0.000 which is less than 0.05. and also the confidence interval does not contain zero. From the statistical analysis, it can be confirmed that there are differences in mean of traffic Crash data before and after the construction of speed hump at 95% confidence interval. There are certain methods to reduce traffic crash but the contribution of the speed hump along Anfo RA to keranyo RA is high by controlled the drivers' behavior in reducing traffic crash.

Table 4- 29 t-test result for traffic Crash data before and after speed hump construction on Bisrate Gebrel to Abo RA road

Paired Samples Test									
Bisrate Gebrel to Abo RA		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
					Lower	Upper			
Pair 1	Befre - After	2.75000	1.60255	.46262	1.73179	3.76821	5.944	11	.000

In this analysis to be significant there are three ways to know whether it is significant or not. The first one is calculated $t_{\text{value}} > t_{\text{critical}} (t \alpha (n-1))$. From the finding as shown the above result the calculated t-value (i.e.5.94) which is higher than the critical t-value at 11 degrees of freedom and 0.05 significance levels that is 1.796. Second the p-value < 0.05 which is P-value = 0.000 which is less than 0.05. and also the confidence interval does not contain zero. From the statistical analysis, it can be confirmed that there are differences in mean of traffic Crash data before and after the construction of speed hump at 95% confidence interval. There are certain methods to reduce traffic crash but the contribution of the speed hump along Bisrate Gebrel to Abo RA is high by controlled the drivers' behavior in reducing traffic crash.

Table 4- 30 t-test result for traffic Crash data before and after speed hump construction on Kara to Wesson road

Paired Samples Test									
Kara to wesson		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
					Lower	Upper			
Pair 1	Befre - After	6.15385	5.39824	1.49720	2.89172	9.41597	4.110	12	.001

In this analysis to be significant there are three ways to know whether it is significant or not. The first one is calculated $t_{\text{value}} > t_{\text{critical}} (t \alpha (n-1))$. From the finding as shown the above result the calculated t-value (i.e.4.11) which is higher than the critical t-value at 12 degrees of freedom and 0.05 significance levels that is 1.782. Second the p-value < 0.05 which is P-value = 0.000 which is less than 0.05. and also the confidence interval does not contain zero. From the statistical analysis, it can be confirmed that there are differences in mean of traffic Crash data before and after the construction of speed hump at 95% confidence interval. There are certain methods to reduce traffic crash but the contribution of the speed hump along Wesson to Kara is high by controlled the drivers' behavior in reducing traffic crash.

Table 4- 31 t-test result for traffic Crash data before and after speed hump construction on Ayer tena to Jemo Michel road

Paired Samples Test									
Ayer tena to Jemo Michel		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
					Lower	Upper			
Pair 1	Befre - After	8.23077	6.73491	1.86793	4.16091	12.30063	4.406	12	.001

In this analysis to be significant there are three ways to know whether it is significant or not. The first one is calculated $t_{\text{value}} > t_{\text{critical}} (t \alpha (n-1))$. From the finding as shown the above result the calculated t-value (i.e.4.406) which is higher than the critical t-value at 12 degrees of freedom and 0.05 significance levels that is 1.782. Second the p-value < 0.05 which is P-value = 0.000 which is

less than 0.05. and also the confidence interval does not contain zero. From the statistical analysis, it can be confirmed that there are differences in mean of traffic Crash data before and after the construction of speed hump at 95% confidence interval. There are certain methods to reduce traffic crash but the contribution of the speed hump along Ayer tena to Jemo Michel is high by controlled the drivers' behavior in reducing traffic crash.



5. CONCLUSIONS AND RECOMMENDATIONS

5.1. CONCLUSIONS

- Concerning on the evaluation of traffic crash after construction of speed hump the reported traffic Crash that is (fatal, Sever and slight) decreased on the study area. Such as Sidest kilo to Afincho ber, Betel RA to keranyo RA, Aware RA to Balderas condominium, Bisrate Gebrel to Abo RA, Kara to Wesson, Anfo RA to Keranyo RA and Ayer tena to Jemo Michel. The total traffic crash decreased by 52%,47.6% ,41.3% 43%,42%,36% and 58% respectively. And also from the statistical analysis, it can be confirmed that there are differences in mean of traffic Crash data before and after the construction of speed hump on all study area at 95% confidence interval. From this it can be conclude that even if, certain methods to reduce traffic crash the contribution of the speed hump along the selected area is high by controlled the drivers' behavior in reducing traffic Crash.
- As per the result of t-test that used to compare the average speed before speed hump and on speed hump of the entire selected hump for this study statically significant. From this it can be conclude that speed hump is the main contributing method to reduce traffic crash along the selected area or it is effective by controlled the drivers' behavior in reducing speed of vehicles.
- Regarding evaluation of 85th percentile speed all the selected hump reduces the 85th percentile speed efficiently that is between 22km/hr - 24km/hr. As a result, it's acceptable from study the posted speed limit for Sidest kilo to Afincho ber road, Aware to Balderas condominium and Betel RA to keranyo RA, Bisrate Gebrel to Abo RA, Kara to Wesson and Anfo RA to Keranyo RA; 30Km/hr. and also for Ayer tena to Jemo Michel posted speed limit 50Km/hr.
- Most of studies shows the characteristic of speed hump length and height determine the speed at which traffic will travel over them that is the shorter the length and greater the height slow vehicle considerably (Ewing, 1999) And also The height of a speed hump must not exceed 100 mm, and it is generally recommended that it does not exceed 75 mm regardless of the profile (01/07, Traffic calming, 2007).

From this it can be conclude that the selected areas have positive impact on this concern. All of the selected speed heights were in between 75mm-100mm.



- Properly design speed hump shows optimum spacing depending on the speed limit in that road; The spacing between speed humps such as 250m, 100m and 75m with the speed of 50Km/hr,40Km/hr. and 30Km/hr. respectively (Traffic Calming Design Guideline 11.07.07. Version 1 / July 2007). From this it can be conclude that for Sidest kilo to Afincho ber the speed limit is 30Km/hr. But the spacing was 246m, so it is better to improved spacing between hump, for Betel RA to keranyo round the speed limit is 30Km/hr. and the spacing between successive speed hump was 148m apart and it is appropriate for this speed. Because there is ramble strip in between the speed hump it is similar to other site. And for Ayer tena to Jemo Michel there is appropriate spacing between speed hump for the posted speed limit, 50Km/hr.
- Concerning on design according to World Resource Institute,2015, The length of modified circle hump varies depending on the posted speed limit in that road such as for 40km/hr and 50km/hr the length of speed hump is 7.5m and 11m respectively. From this it can be conclude that for street having speed hump and its speed limit 40Km/hr and 50km/hr. such as sidest kilo to Afocho ber ,Kra to Wesson, Bisrate Gebrel to Abo RA the posted speed limit is 30Km/hr. But the constructed speed hump for 40Km/ hr. For Ayer tena to Gemo Michel the posted speed limit is 50 Km/hr. and the length of speed hump is 10.8 m so it is approximately 11m so it is appropriate.



5.2. RECOMMENDATIONS

For future study into the evaluation of effectiveness of speed hump may include the following point:

- From the time when the speed hump Constructed were a relatively short period of time and the researcher found its well effective due to reduced crash, despite quality of paint relatively need consideration for the reason it loose its brightness through time more over as soon as possible the painting should paint immediately after construction.
- To make the Constructed speed hump work effectively the appropriate speed limit and the -warning sign that is there is speed hump ahead should be placed. During study period the street where Betel round about to Keranyo round about, Balderas to aware round about Anfo RA to Keranyo RA not have warning sign that indicate there is a speed hump ahead. More over on one site from the study area (i.e. Anfo RA to Keranyo RA) not installed reflector to reflect at night so it is better install reflectors to make visible at night.
- From the selected area that is Aware to Balderas there is only one speed hump. But from different study to be more effective it is better to Constructed speed hump successively.
- For future study it is better to consider the traffic volume whether vehicle divert their way due to Constructed speed hump or not more over it influence the neighbor road or not, noise on neighbor building, mechanical effect on vehicle and psychological effect on passengers. In addition to this study consider only small car so for future it is better to take different composition of vehicle.



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APPENDIX A:

የ 2010 ዓ/ም ከሀምሌ 1/2009 ዓ/ም-ሰኔ 30/2010 ዓ/ም

Table A- 1 የ 2010 ዓ/ም ከሀምሌ 1/2009 ዓ/ም-ሰኔ 30/2010 ዓ/ም

24 አሽከርካሪውን ለአደጋ ያበቁት ምክንያቶች/መንስኤ/					አደጋ				ድምር
ተ/ቁ	መንገድ	ሞት	ከባድ	ቀላል	የንብረት				
1	ሰክሮ መንዳት	3	22	8	120			153	
2	በዕዕ ደንዝዝ መንዳት	-	2	1	50			53	
3	ቀኝን ለቆ በመንዳት	21	-	4	465			490	
4	ለተሸከርካሪ ቅድሚያ	19	48	22	5984			6073	
5	ለእግረኛ ቅድሚያ	133	1342	741	149			2365	
6	ረቀት ጡብቆ	90	57	49	7255			7451	
7	ከረብታ ጫፍ ላይ	-	6	-	73			79	
8	ጠምዛዛ/ከርብ/	-	-	-	211			211	
9	ከቀደመ በኋላ	10	5	3	1160			1178	
10	ከተወሰነ ፍጥነት	70	139	112	2420			2741	
11	አለአግባብ መቅደም	16	7	10	1577			1610	
12	አለአግባብ	26	12	11	1340			1389	
13	የትራፊክ ፖሊስ	-	2	-	311			313	
14	የትራፊክ መብራት	-	27	6	193			226	
15	የቁም ምልክት	-	-	-	162			162	
16	ቅድሚያ ስጥ	4	42	9	1027			1082	
17	ከቆመበት አለአግባብ	2	7	5	754			768	
18	አለአግባብ በማቆም	-	1	-	414			415	
19	በድካም ወይም	-	-	-	7			7	
20	በሀሳብ በመዋጥ	-	2	-	20			22	
21	አለአግባብ	-	-	-	6			6	
22	አለአግባብ በመጫን	-	-	1	158			159	
23	የፍሬን ጉድለት	-	-	2	127			129	
24	የጎማ መውለቅ	-	-	-	474			474	
25	የጎማ መፈንዳት	-	-	-	10			10	
26	የመሪ ጉድለት	-	-	-	116			116	
27	የመንገድ ጉድለት	-	-	-	29			29	
28	የእግረኛ ጉድለት	3	-	3	0			6	
29	ሌላ	11	93	47	64			215	
30	ያልታወቀ	48	89	40	252			429	
ድምር		456	1903	1074	24928			28361	



24 አሽከርካሪውን ለአደጋ በቁት ምክንያቶች /መንስኤ/									
ተ/ቁ	መንገድ				አደጋው				ድምር
					ያስከተለው ጉዳት				
					ሞት	የአካል	የአካል	ጉዳት	
1	ሰክሮ መንዳት					0	0	86	86
2	መንዳት					0	0	45	45
3	ቀኝን ለቆ በመንዳት				35	15	32	1077	1159
4	ቅድሚያ				2	100	56	6918	7076
5	ባለመስጠት				250	1380	777	482	2889
6	ባለመንዳት				27	47	50	7398	7522
7	በመቅደም				4	0	0	0	4
8	መንገድ ላይ					0	1	38	39
9	ድንገት ታጥፎ					8	4	1089	1101
10	ከተወሰነ ፍጥነት በላይ በመንዳት				6	82	107	2166	2361
11	መቅደም				7	26	0	1942	1975
12	አለአግባብ በመቅደም				21	16	0	2168	2205
13	የትራፊክ ፖሊስ ትዕዛዝ በመጣስ				1	0	0	63	64
14	በመታስ					0	0	203	203
15	በመጣስ					0	0	76	76
16	የሚለውን ምልክት					39	2	836	877
17	አለአግባብ				2	2	4	308	316
18	በማቆም				4	0	0	263	267
19	በመተኛት				1	0	1	9	11
20	በሀሳብ በመዋጥ					1	1	0	2
21	በማብራት					0	0	0	0
22	አለአግባብ በመጫን					0	0	22	22
23	የፍሬን ጉድለት					0	0	60	60
24	የጎማ መውለቅ					0	0	0	0
25	የጎማ መረንዳት					0	0	0	0
26	የመሪ ጉድለት					0	0	49	49
27	የመንገድ ጉድለት					0	0	0	0
28	የእግረኛ ጉድለት					0	2	2	4
29	ሌላ				14	109	73	427	623
30	ያልታወቀ				84	101	33	292	510
ድምር					458	1926	1143	26019	29546



APPENDIX B: Study area

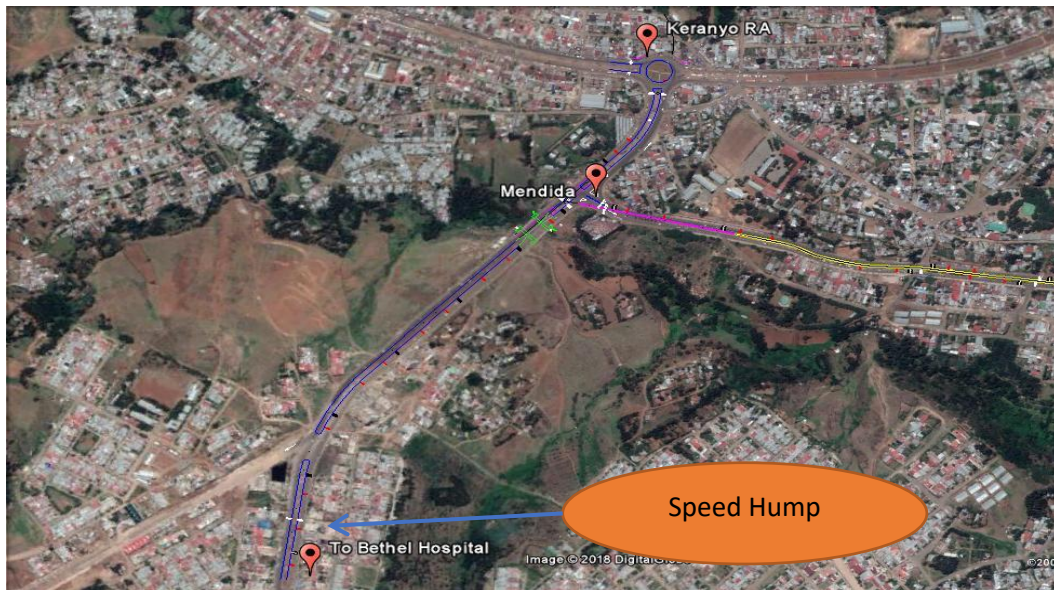


Figure B- 1 Betel to Kolfe keranyo round about relative location map

Source:Google earth



Figure B- 2 Speed hump on Betel RA to Keranyo RA

Source :photo take on site



Figure B- 3 Aware round about to Balderas condominium round about relative location map

Source:Google earth



Figure B- 4 Speed hump on Balderas to Aware round about



Figure B- 5 Speed hump on Ayer tena to Jemo



Figure B- 6 Speed hump on Balderas to Aware round about

Source:Photo take on site



Figure B- 7 Speed hump on Kara to Wesson



Figure B- 8 Speed hump on Kara to Wesson



Figure B- 9 Speed hump on Bisrate Gebrel to Abo RA

Source: Google



Figure B- 10 Speed hump on Bisrate Gebrel to Abo RA

Source:Photo take on site



Figure B- 11 Speed hump on Anfo RA to Keranyo



Figure B- 12 Speed hump on Anfo RA to Keranyo

Source:Photo take on site

APPENDIX C: Spot speed data

Table C- 1 Spot speed data on Sidest kilo to Afincho ber road

No.	Speed [Km/hr.]			No.	Speed [Km/hr.]		
	50m before hump	50m after hump	At speed hump		50m before hump	50m after hump	At speed hump
1	39	34	23	26	44	34	17
2	37	32	15	27	36	23	10
3	40	36	22	28	45	39	12
4	27	27	23	29	41	33	16
5	41	31	20	30	39	25	18
6	46	35	11	31	41	41	16
7	49	37	14	32	37	25	19
8	39	32	16	33	38	35	13
9	28	33	14	34	53	22	22
10	45	29	18	35	37	27	12
11	36	34	16	36	43	24	14
12	36	39	21	37	48	35	21
13	38	31	15	38	40	31	23
14	38	31	14	39	45	32	22
15	37	37	21	40	37	36	23
16	39	24	16	41	36	23	18
17	40	31	15	42	41	30	13
18	37	35	14	43	40	30	10
19	44	33	15	44	43	28	26
20	37	32	13	45	40	35	17
21	41	31	14	46	37	38	11
22	46	29	12	47	50	22	13
23	36	32	19	48	44	24	10
24	43	29	12	49	43	36	25
25	37	32	14	50	49	30	9

No.	Speed [Km/hr.]			No.	Speed [Km/hr.]		
	50m before hump	50m after hump	At speed hump		50m before hump	50m after hump	At speed hump
51	29	41	22	76	30	32	19
52	32	38	13	77	40	34	11
53	33	34	22	78	36	39	12
54	32	35	23	79	34	32	14
55	36	33	19	80	36	26	17
56	41	26	13	81	32	40	16
57	44	37	14	82	33	26	19
58	34	31	15	83	48	32	23
59	31	32	16	84	32	41	21
60	40	34	18	85	38	27	15
61	31	32	17	86	43	42	12
62	29	35	21	87	35	23	21
63	29	31	15	88	40	31	22
64	33	29	14	89	32	40	24
65	33	38	23	90	32	36	22
66	32	35	18	91	28	40	20
67	34	32	17	92	35	32	16
68	35	35	13	93	38	32	12
69	33	33	15	94	29	27	24
70	39	42	13	95	40	34	18
71	27	29	13	96	38	39	13
72	37	39	14	97	51	37	14
73	41	33	21	98	41	29	12
74	31	31	12	99	43	37	25
75	39	34	14	100	49	31	11

Table C- 2 Spot speed data on Aware to Balderas condominium

No.	Speed (Km/hr)			No	Speed (Km/hr)		
	50m befor Speed hump	50m after speed hump	AT SPEED hamp		50m befor Speed hump	50m after speed	AT SPEED hamp
1	36	32	22	26	39	29	17
2	43	33	19	27	41	42	12
3	27	29	14	28	21	22	21
4	46	42	18	29	22	21	14
5	44	35	17	30	44	35	14
6	34	29	19	31	36	26	21
7	25	26	13	32	46	33	20
8	26	27	22	33	34	21	13
9	28	25	15	34	41	42	17
10	30	30	24	35	24	22	18
11	52	42	25	36	34	34	20
12	28	31	13	37	39	41	14
13	43	42	22	38	31	27	21
14	35	36	26	39	38	29	16
15	35	37	25	40	29	30	22
16	45	41	13	41	34	37	23
17	44	34	21	42	42	41	13
18	39	25	26	43	39	37	20
19	37	33	12	44	36	31	22
20	42	38	18	45	44	42	24
21	36	37	23	46	40	39	14
22	30	27	19	47	41	38	21
23	35	34	9	48	35	42	24
24	32	33	27	49	42	39	15
25	43	41	15	50	30	29	17

Speed (Km/hr)				Speed (Km/hr)			
No.	50m before Speed hump	50m after speed hump	AT SPEED hump	No	50m before Speed hump	50m after speed	AT SPEED hump
51	45	41	22	76	23	21	14
52	42	32	19	77	43	44	22
53	35	34	9	78	35	32	25
54	30	28	26	79	46	45	12
55	30	28	15	80	35	36	19
56	29	30	18	81	41	40	22
57	30	31	13	82	25	26	20
58	51	45	15	83	33	36	10
59	28	28	15	84	41	38	26
60	44	41	14	85	31	33	15
61	36	37	20	86	39	34	16
62	35	34	19	87	29	30	13
63	44	40	14	88	32	23	22
64	45	39	19	89	43	44	15
65	40	27	18	90	38	37	14
66	38	28	20	91	36	33	17
67	40	35	14	92	45	28	18
68	37	29	13	93	40	27	14
69	30	33	14	94	42	42	16
70	34	31	25	95	30	28	12
71	30	30	24	96	38	29	13
72	44	39	12	97	37	33	18
73	39	40	21	98	39	35	20
74	40	35	23	99	44	36	11
75	21	22	25	100	42	38	13

Table C- 3 Spot speed data on Betel RA to keranyo RA

No. of car	Speed(Km/hr)			No. of car	Speed(Km/hr)		
	50m befor SH	50m after SH	AT SPEED hamp		50m befor SH	50m after SH	AT SPEED hamp
1	30	13	17	26	27	25	16
2	35	19	25	27	29	20	20
3	39	14	19	28	45	22	13
4	51	18	26	29	52	29	18
5	43	19	22	30	34	27	16
6	44	13	12	31	42	26	24
7	46	14	9	32	36	25	24
8	53	15	18	33	38	27	27
9	31	17	17	34	36	21	24
10	28	19	15	35	43	24	14
11	39	17	17	36	29	25	9
12	63	16	25	37	36	28	21
13	35	15	16	38	34	26	18
14	45	18	21	39	47	25	17
15	44	14	16	40	24	27	15
16	33	19	18	41	42	29	22
17	39	14	15	42	43	26	17
18	26	17	16	43	43	23	21
19	43	21	11	44	40	19	26
20	40	22	11	45	55	21	19
21	26	15	22	46	41	26	16
22	44	16	15	47	43	18	15
23	41	17	22	48	40	22	22
24	35	22	13	49	42	25	22
25	40	23	15	50	44	21	21

No. of car	Speed(Km/hr)			No. of car	Speed(Km/hr)		
	50m before SH	50m after SH	AT SPEED hamp		50m before SH	50m after SH	AT SPEED hamp
51	29	23	24	76	45	28	17
52	33	22	21	77	53	25	23
53	46	27	15	78	30	25	23
54	37	28	13	79	42	23	21
55	54	19	18	80	39	24	26
56	36	22	21	81	55	25	19
57	43	21	13	82	37	28	14
58	47	19	20	83	45	26	16
59	26	22	19	84	46	34	17
60	34	27	20	85	32	28	19
61	45	23	22	86	40	28	12
62	49	33	27	87	43	23	17
63	43	25	22	88	46	21	18
64	42	19	12	89	40	24	22
65	42	21	10	90	47	21	21
66	29	25	21	91	43	24	18
67	53	19	18	92	41	27	22
68	30	19	18	93	52	21	15
69	30	26	15	94	45	20	10
70	33	23	23	95	41	24	22
71	36	27	16	96	32	19	19
72	40	22	21	97	39	22	18
73	39	27	15	98	51	23	15
74	42	20	19	99	43	21	13
75	45	26	15	100	29	28	22

Table C- 4 Spot speed data on Ayer tena to Jemo Michel

spot speed from Ayer tena to Jemo Michel							
No	50m before Speed hump	50m after speed hump	AT SPEED hump	No	50m before Speed hump	50m after speed	AT SPEED hump
1	40	48	15	26	31	44	18
2	50	45	25	27	29	41	22
3	49	39	21	28	55	42	14
4	63	44	23	29	52	46	20
5	43	48	24	30	34	44	18
6	48	51	15	31	42	42	29
7	46	43	9	32	65	42	27
8	53	46	20	33	38	36	25
9	42	51	17	34	37	37	26
10	38	39	16	35	44	33	12
11	39	52	17	36	28	38	11
12	60	39	21	37	36	38	21
13	45	48	14	38	33	35	19
14	35	46	23	39	47	36	16
15	48	52	16	40	61	35	15
16	64	44	20	41	42	29	21
17	39	51	15	42	44	48	19
18	29	38	17	43	59	27	20
19	58	49	12	44	58	39	25
20	40	44	11	45	55	32	18
21	36	42	24	46	56	27	15
22	49	45	15	47	42	28	16
23	41	44	25	48	59	37	22
24	33	41	14	49	42	35	21
25	40	39	13	50	44	39	24

spot speed from Ayer tena to Jemo Michel							
No	50m before Speed hump	50m after speed hump	AT SPEED hump	No	50m before Speed hump	50m after speed	AT SPEED hump
51	33	28	25	76	46	29	18
52	32	39	22	77	61	26	24
53	46	38	14	78	31	28	25
54	64	29	12	79	44	30	21
55	55	48	17	80	66	34	26
56	37	37	22	81	55	36	19
57	49	32	14	82	37	28	15
58	50	29	20	83	44	31	18
59	36	32	25	84	49	36	19
60	33	38	29	85	28	38	19
61	50	48	28	86	57	40	14
62	48	34	29	87	44	26	18
63	44	27	24	88	45	27	20
64	43	29	12	89	57	35	22
65	56	41	11	90	47	31	23
66	52	36	21	91	53	34	19
67	53	41	18	92	41	43	22
68	28	39	19	93	52	32	17
69	31	35	28	94	45	43	10
70	32	26	24	95	41	34	22
71	36	38	17	96	33	29	21
72	42	33	23	97	39	34	18
73	53	41	17	98	51	26	15
74	53	31	20	99	43	34	16
75	46	43	16	100	29	38	24

Table C- 5 Spot speed data on Wesson to Kara

No	Spot speed (Km/hr)			No	Spot speed (Km/hr)		
	50mbefor SH	50m after SH	AT SPEED hamp		50mbefor SH	50m after SH	AT SPEED hamp
1	37	32	22	26	39	29	16
2	42	31	21	27	42	42	11
3	28	29	16	28	22	24	21
4	52	40	20	29	21	23	17
5	46	35	19	30	53	35	19
6	33	30	20	31	35	26	21
7	26	26	11	32	51	36	22
8	25	25	25	33	33	22	10
9	29	26	17	34	42	41	17
10	31	30	22	35	24	23	18
11	53	45	26	36	35	36	22
12	27	31	16	37	40	42	16
13	50	42	21	38	35	29	23
14	34	36	26	39	39	31	16
15	34	35	25	40	30	30	24
16	45	42	12	41	32	36	21
17	42	34	20	42	45	41	14
18	39	25	26	43	39	39	22
19	37	35	16	44	37	33	22
20	41	38	20	45	43	42	22
21	36	37	21	46	44	40	17
22	34	28	19	47	41	36	14
23	35	25	10	48	35	42	22
24	31	31	26	49	43	41	16
25	44	41	18	50	30	29	19

No	Spot speed (Km/hr)			No	Spot speed (Km/hr)		
	50m before SH	50m after speed	AT SPEED hamp		50m before SH	50m after speed	AT SPEED hamp
51	47	43	20	76	23	23	14
52	41	32	11	77	44	46	27
53	34	34	10	78	36	32	26
54	31	30	27	79	45	44	13
55	30	29	15	80	35	38	19
56	29	32	17	81	41	42	24
57	31	33	15	82	24	26	10
58	50	45	10	83	33	34	11
59	28	28	14	84	40	36	25
60	51	43	15	85	31	32	17
61	36	39	22	86	39	34	14
62	35	37	21	87	29	32	13
63	44	40	14	88	32	22	22
64	45	39	19	89	42	46	17
65	42	28	18	90	38	39	15
66	38	27	22	91	36	35	19
67	41	35	16	92	46	30	18
68	37	28	15	93	41	28	16
69	33	35	12	94	40	44	14
70	34	33	24	95	32	29	13
71	29	32	25	96	38	28	11
72	44	38	13	97	37	35	19
73	39	42	24	98	40	34	15
74	41	35	21	99	43	38	10
75	21	22	25	100	44	37	13

Table C- 6 Spot speed data on Bistrate Gebrel to Abo RA

No	Spot Speed(Km/hr)			No	Spot Speed(Km/hr)		
	50m befor SH	50m after SH	AT SPEED hamp		50m befor SH	50m after SH	AT SPEED hamp
1	41	38	22	26	45	24	19
2	28	36	23	27	37	24	22
3	41	38	19	28	47	41	12
4	48	39	22	29	43	40	11
5	42	31	27	30	40	41	15
6	46	39	25	31	22	43	16
7	50	37	16	32	54	31	13
8	21	39	17	33	39	38	11
9	49	32	15	34	54	25	22
10	25	38	20	35	39	39	12
11	52	39	12	36	26	39	24
12	52	39	21	37	28	41	21
13	29	36	22	38	39	33	17
14	28	36	26	39	43	32	19
15	39	39	27	40	51	36	20
16	52	40	24	41	37	27	17
17	42	40	21	42	42	31	21
18	38	39	15	43	41	31	17
19	45	40	13	44	45	30	21
20	53	36	18	45	42	24	22
21	42	32	17	46	37	38	19
22	46	40	15	47	56	25	18
23	38	36	24	48	29	25	22
24	44	41	13	49	45	36	19
25	51	33	14	50	29	31	10

No	Spot Speed(Km/hr)			No	Spot Speed(Km/hr)		
	50m before SH	50m after SH	AT SPEED hamp		50m before SH	50m after SH	AT SPEED hamp
51	28	42	21	76	32	33	11
52	49	38	12	77	43	35	14
53	28	41	14	78	55	45	12
54	28	41	10	79	34	33	16
55	37	41	18	80	54	27	26
56	44	29	11	81	33	41	20
57	45	39	11	82	35	27	16
58	26	32	15	83	48	34	17
59	48	33	18	84	55	42	18
60	23	34	21	85	39	28	13
61	49	32	17	86	43	43	14
62	49	40	14	87	36	25	10
63	24	31	20	88	42	32	13
64	51	29	19	89	53	42	14
65	56	38	17	90	43	37	17
66	26	41	18	91	35	45	23
67	34	33	15	92	36	34	18
68	51	35	10	93	39	35	17
69	33	34	13	94	32	28	22
70	41	43	11	95	43	35	18
71	22	29	10	96	39	41	19
72	39	45	19	97	52	38	13
73	42	35	21	98	44	40	15
74	56	31	25	99	46	27	16
75	41	34	12	100	50	29	18

Table C- 7 Spot speed data on Anfo RA to Keranyo RA

No	Spot speed (Km/hr)			No	Spot speed (Km/hr)		
	50mbefor SH	50m after SH	AT SPEED hamp		50mbefor SH	50m after speed	AT SPEED hamp
1	32	31	16	26	35	29	16
2	39	32	19	27	37	43	11
3	23	38	13	28	23	21	19
4	42	24	17	29	26	20	13
5	40	34	16	30	40	36	14
6	44	30	18	31	32	27	20
7	25	27	10	32	39	34	19
8	26	26	16	33	30	22	11
9	24	27	13	34	41	43	17
10	26	31	23	35	23	23	19
11	48	40	24	36	30	35	16
12	24	39	10	37	35	41	15
13	39	23	20	38	46	28	22
14	45	35	23	39	33	29	17
15	31	36	24	40	44	40	16
16	38	22	10	41	46	38	23
17	40	35	19	42	38	41	11
18	35	26	22	43	35	37	19
19	32	32	11	44	31	38	17
20	38	37	17	45	41	43	23
21	32	36	16	46	36	39	14
22	45	26	18	47	37	37	17
23	31	32	10	48	31	41	22
24	44	32	23	49	38	39	15
25	39	25	14	50	26	29	16

No	Spot speed (Km/hr)			No	Spot speed (Km/hr)		
	50mbefor SH	50m after SH	AT SPEED hamp		50mbefor SH	50m after SH	AT SPEED hamp
51	41	21	17	76	45	21	13
52	42	39	19	77	40	43	21
53	31	35	10	78	35	31	20
54	26	27	22	79	42	43	12
55	26	27	14	80	31	37	19
56	44	31	17	81	41	41	21
57	26	32	12	82	25	25	19
58	51	44	15	83	33	35	24
59	28	28	14	84	41	37	21
60	40	42	13	85	31	32	14
61	32	37	19	86	39	33	14
62	46	35	20	87	29	31	14
63	41	41	14	88	34	24	21
64	39	39	19	89	43	43	14
65	42	28	17	90	34	36	15
66	38	27	17	91	36	40	16
67	36	34	14	92	41	29	19
68	33	29	13	93	41	26	15
69	30	32	13	94	43	41	16
70	31	31	23	95	34	27	13
71	44	32	22	96	33	28	14
72	40	38	12	97	32	31	19
73	35	41	20	98	39	34	21
74	36	36	23	99	49	35	12
75	24	22	21	100	42	37	14

APPENDEX D: Spot speed distribution

Figure D- 1 Distribution of Spot Speed vs number of vehicle at three locations (Awaray RA to Balderas condominium)

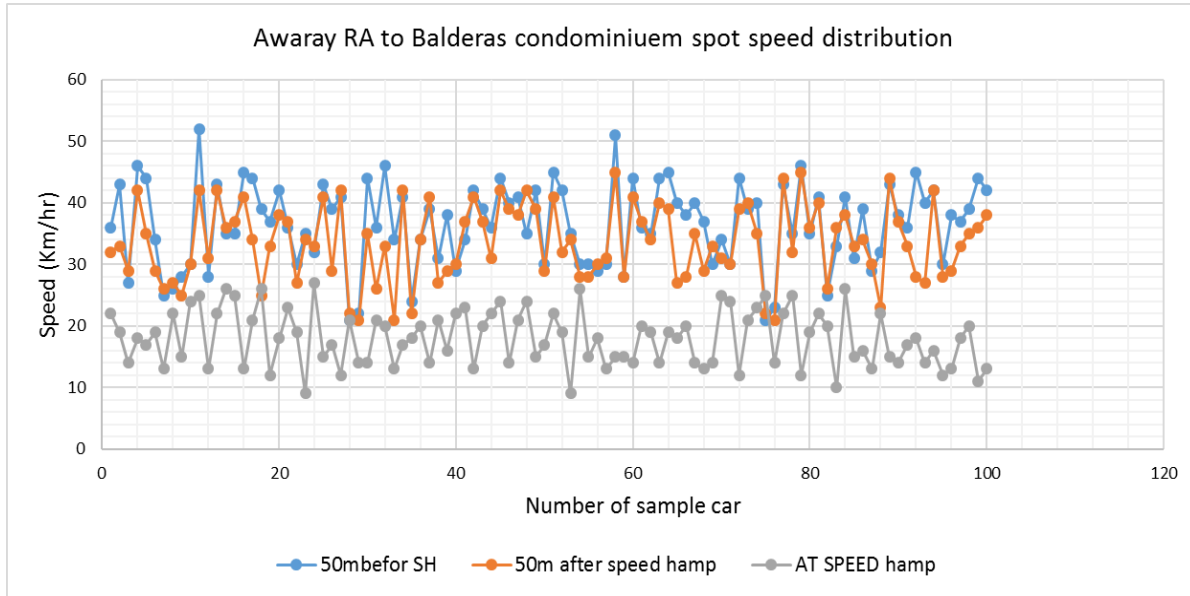


Figure D- 2 Distribution of Spot Speed vs number of vehicle at three locations (Bethel RA to Keranyo RA)

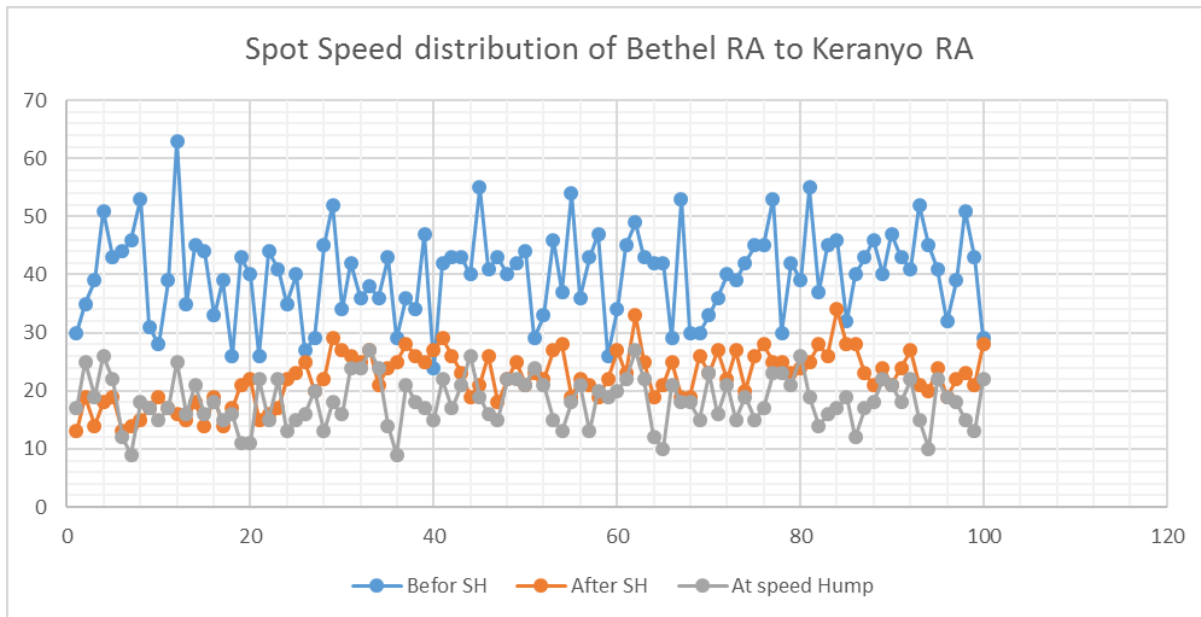


Figure D- 3 Distribution of Spot Speed vs. number of vehicle at three locations (Ayer tena to Jemo micael)

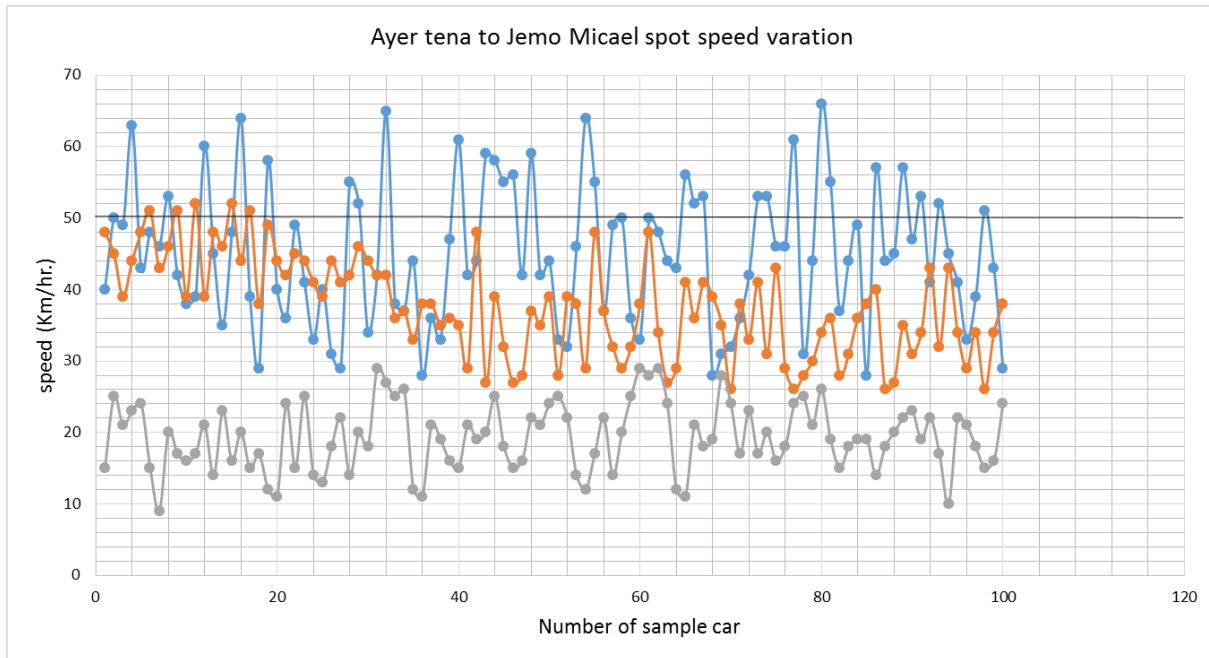


Figure D- 4 Distribution of Spot Speed vs number of vehicle at three locations (Kara to Wesson)

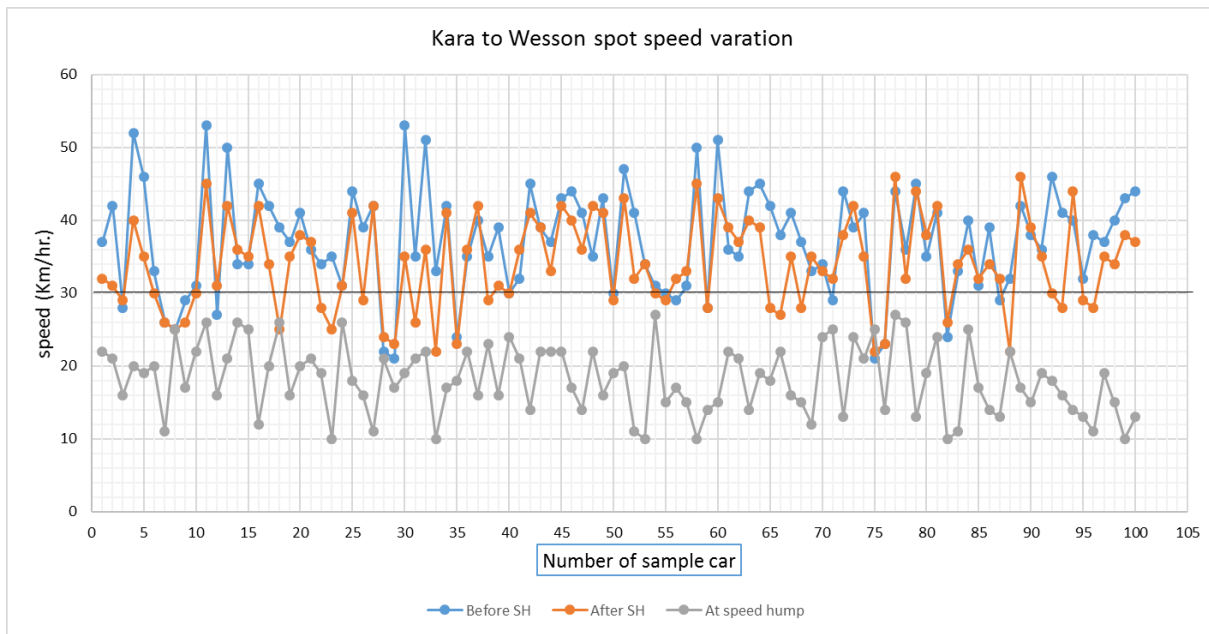


Figure D- 5 Distribution of Spot Speed vs number of vehicle at three locations (Bisrate gebrel to Abo RA)

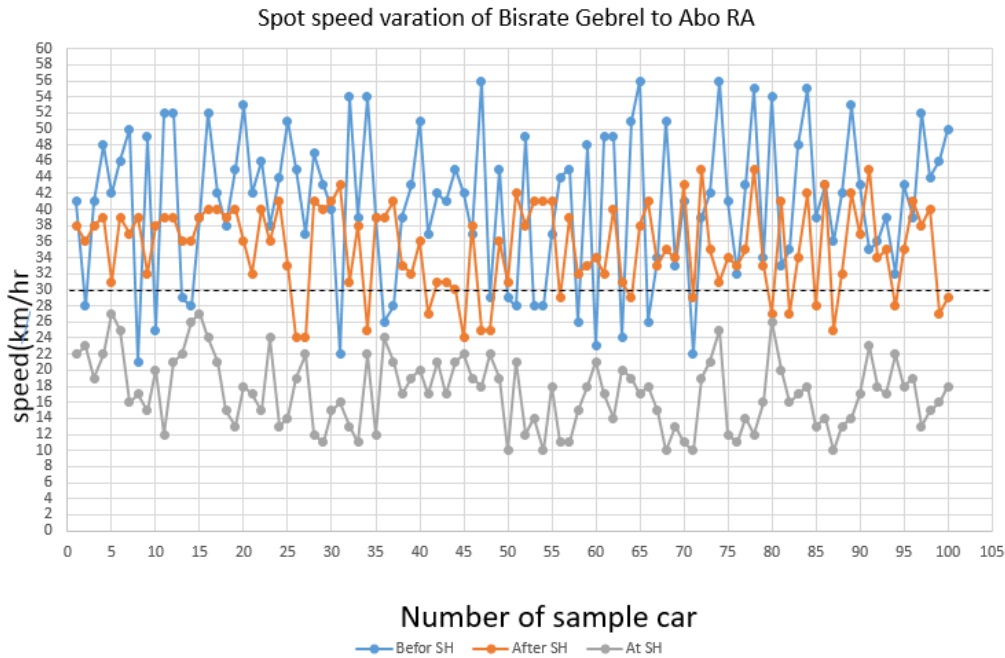
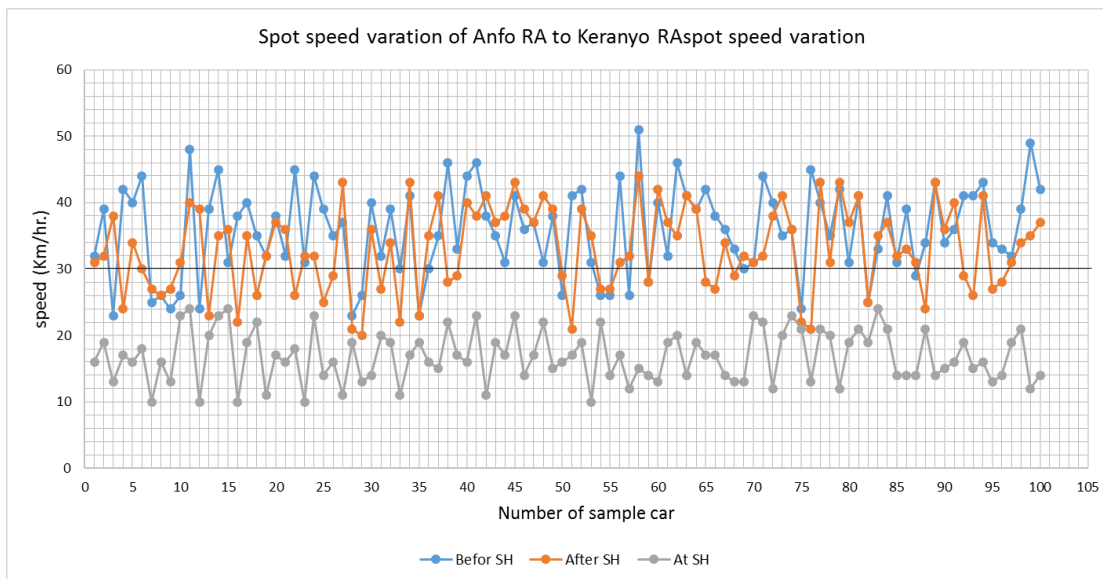


Figure D- 6 Distribution of Spot Speed vs number of vehicle at three locations (Anfo RA to Keranyo RA)



APPENDEX E: Frequency distribution before speed hump

Table E- 1 frequency distribution table for Sidest kilo to Afincho ber road spot speed study before approaching the speed hump

speed class(Km/h	class mid value(Ui)	class frequency (number observation	fiui	percentage of observation in a class	cummlative percentage observation in aclass	fi(ui-u)2	mean speed(u)	$\sqrt{\sum fi(ui-u)^2/n-1}$
27-29	28	8	224	8.00	8.00	808.02	38.05	5.7
30-32	31	11	341	11.00	19.00	628.69	38.56	
33-35	34	11	374	11.00	30.00	228.73	38.56	
36-38	37	24	888	24.00	54.00	58.41	38.56	
39-41	40	23	920	23.00	77.00	47.69	38.56	
42-44	43	10	430	10.00	87.00	197.14	38.56	
45-47	46	5	230	5.00	92.00	276.77	38.56	
48-50	49	6	294	6.00	98.00	653.96	38.56	
51-53	52	2	104	2.00	100.00	361.27	38.56	
		100	3805			3260.67		

sidist killo RA to Afincho ber befor SH

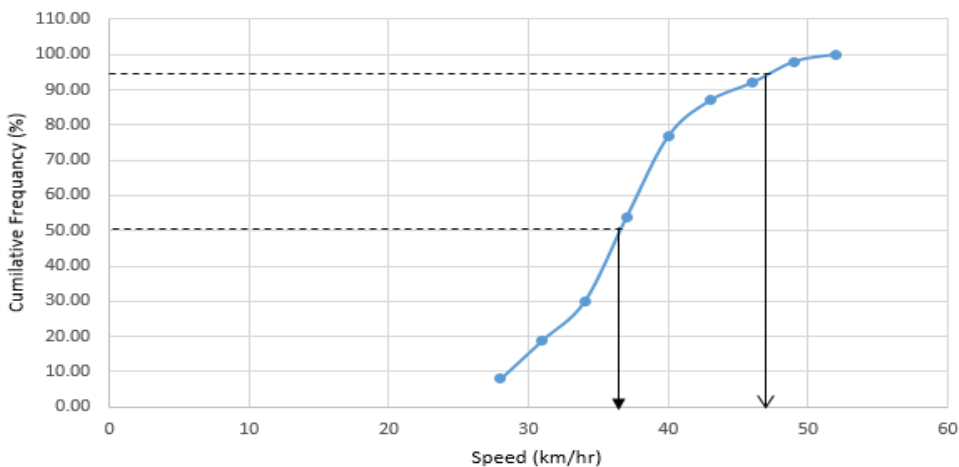


Figure E- 1 Cumulative frequency curve with 85th & 50th level marked by dotted lines before hump



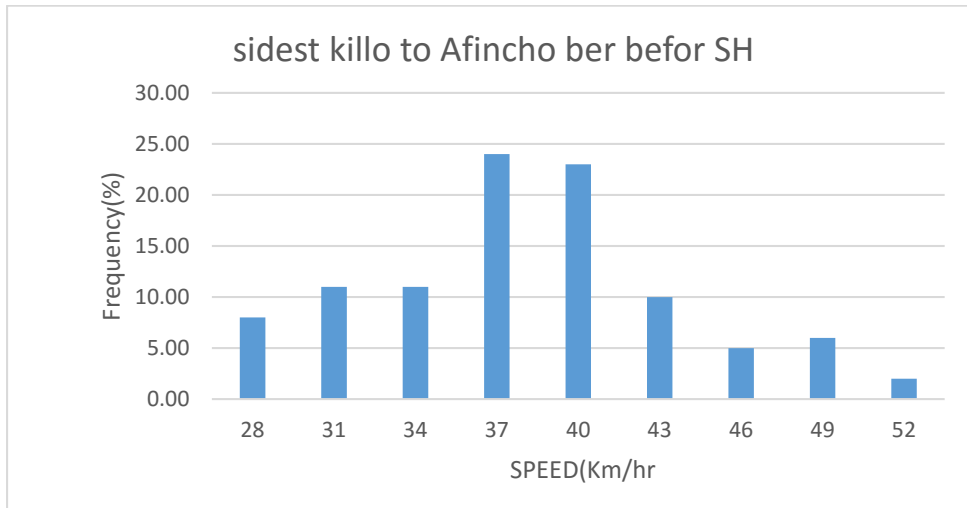


Figure E- 2 Frequency histogram before speed hump

Table E- 2 frequency distribution table for Aware to Balderas road spot speed study before approaching the speed hump

speed class(Km/h	class mid value(Ui)	class frequency in a class(no.of observation in a class,fi)	fiui	percentage of observation in a class	cummlative perpercentage observation in aclass	fi(ui-u)2	mean speed(u)	$\sqrt{\sum fi(ui-u)^2/n-1}$
21-23.5	22	4	88	4.00	4	860.84	36.67	6.7
24-26.5	25	4	100	4.00	8.00	544.76	36.67	
27-29.5	28	7	196	7.00	15.00	526.18	36.67	
30-32.5	31	13	403	13.00	28.00	417.94	36.67	
33-35.5	34	14	476	14.00	42.00	99.80	36.67	
36-38.5	37	13	481	13.00	55.00	1.42	36.67	
39-41.5	40	17	680	17.00	72.00	188.51	36.67	
42-44.5	43	19	817	19.00	91.00	761.31	36.67	
45-47.5	46	7	322	7.00	98.00	609.34	36.67	
48-50.5	49	0	0	0.00	98.00	0.00	36.67	
51-53.5	52	2	104	2.00	100.00	470.02	36.67	
		100	3667			4480.11		

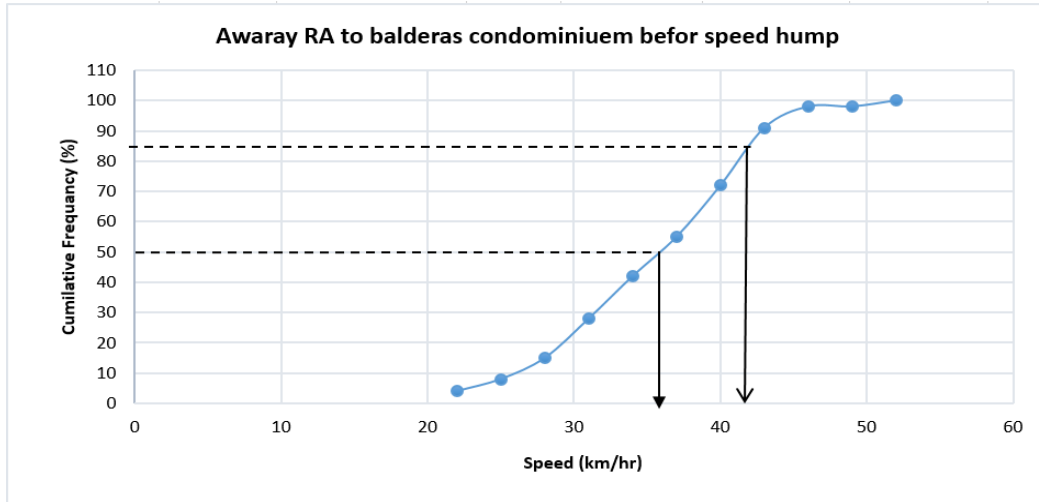


Figure E- 3 Cumulative frequency curve with 85th & 50th level marked by dotted lines before hump

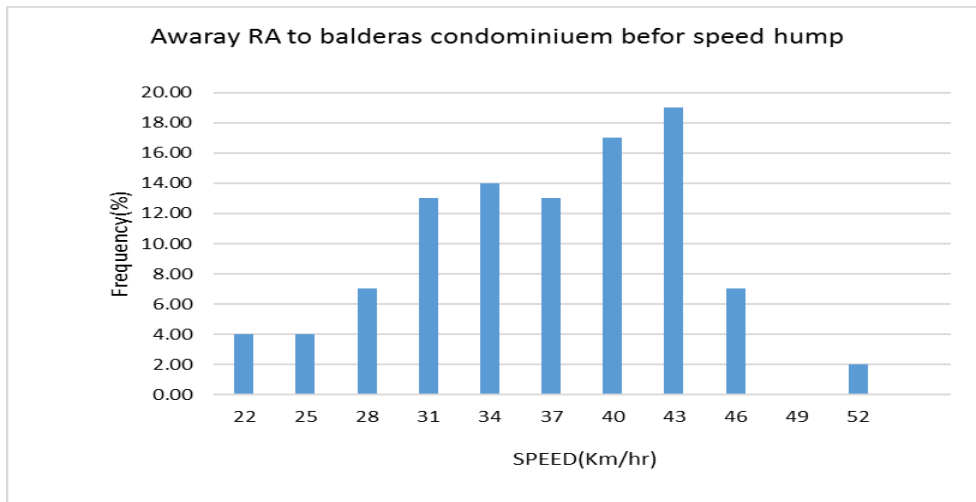


Figure E- 4 Frequency histogram before hump

Table E- 3 Frequency distribution table for Betel RA to keranyo RA road spot speed study before speed hump

speed class(Km/h)	class mid value(Uj)	class frequency (number observation in a class,fi)	fiui	percentage of observation in a class	cummlativepercent age observation in aclass	fi(ui-u)2	mean speed(u)	$\sqrt{\sum fi(ui-u)^2/n-1}$
24-26.5	25	4	100	4.00	4	921.73	40.18	7.5
27-29.5	28	7	196	7.00	11.00	1038.47	40.18	
30-32.5	31	7	217	7.00	18.00	589.91	40.18	
33-35.5	34	9	306	9.00	27.00	343.73	40.18	
36-38.8	37	8	296	8.00	35.00	80.90	40.18	
39-41.5	40	17	680	17.00	52.00	0.55	40.18	
42-44.5	43	22	946	22.00	74.00	174.95	40.18	
45-47.5	46	14	644	14.00	88.00	474.21	40.18	
48-50.5	49	1	49	1.00	89.00	77.79	40.18	
51-53.5	52	7	364	7.00	96.00	977.99	40.18	
54-56.5	55	4	220	4.00	100.00	878.53	40.18	
		100	4018			5558.76		

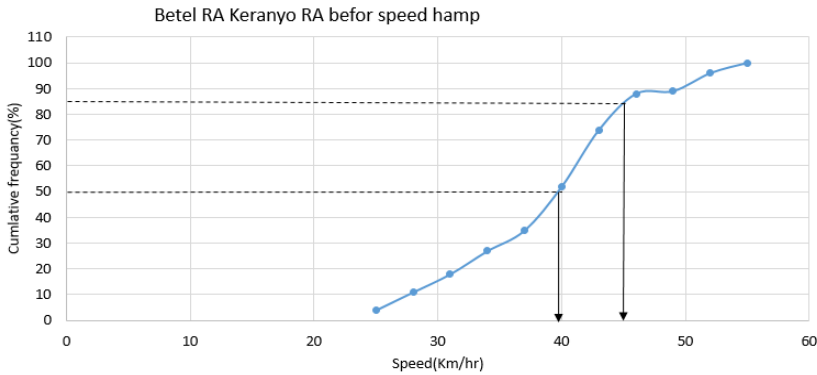


Figure E- 5 Cumulative frequency curve with 85th & 50th level marked by dotted lines before hump

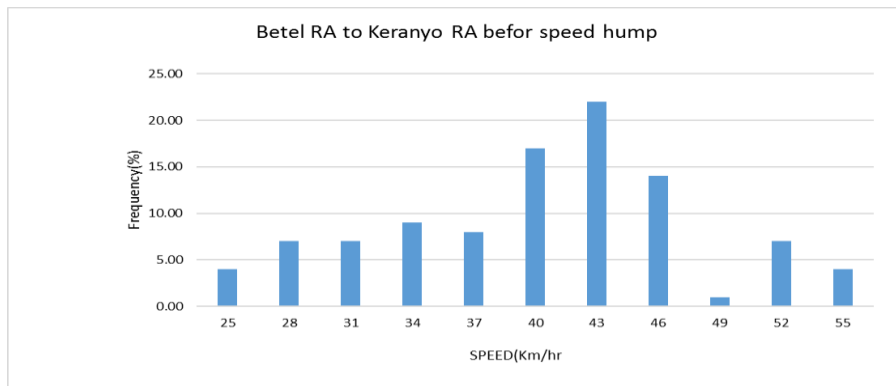


Figure E- 6 Frequency histogram before speed hump



Table E- 4 Frequency distribution table for Ayer tena to Jemo Michel road spot speed study before approaching the speed hump

speed class(Km/h)	class mid value(Ui)	class frequency in a class(no.of observation in a class;fi)	fiui	percentage of observation in a class	cummlative perercentage observation in aclass	fi(ui-u)2	mean speed(u)	$\sqrt{\sum fi(ui-u)^2/n-1}$
28-31	30	9	270	9.00	9	2224.07	45.72	9.7
32-35	34	9	306	9.00	18.00	1236.23	45.72	
36-39	38	12	456	12.00	30.00	715.18	45.72	
40-43	42	15	630	15.00	45.00	207.58	45.72	
44-47	46	16	736	16.00	61.00	1.25	45.72	
48-51	50	11	550	11.00	72.00	201.50	45.72	
52-55	54	12	648	12.00	84.00	822.70	45.72	
56-59	58	8	464	8.00	92.00	1206.39	45.72	
60-63	62	4	248	4.00	96.00	1060.15	45.72	
64-67	66	4	264	4.00	100.00	1645.11	45.72	
		100	4572			9320.16		

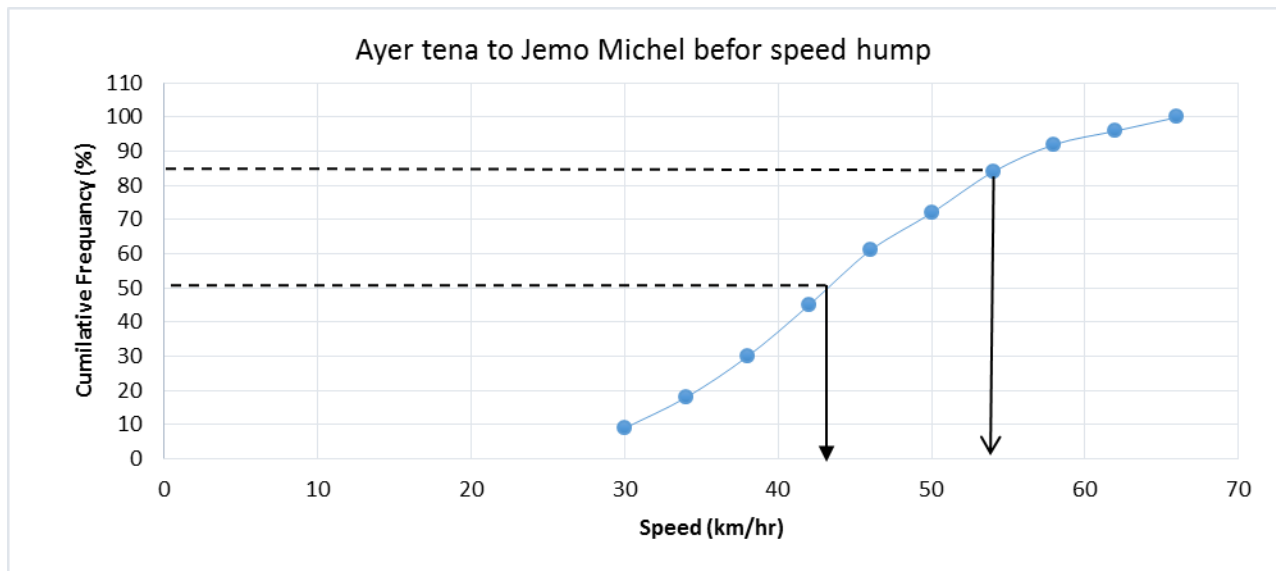


Figure E- 7 Cumulative frequency curve with 85th & 50th level marked by dotted lines before speed hump



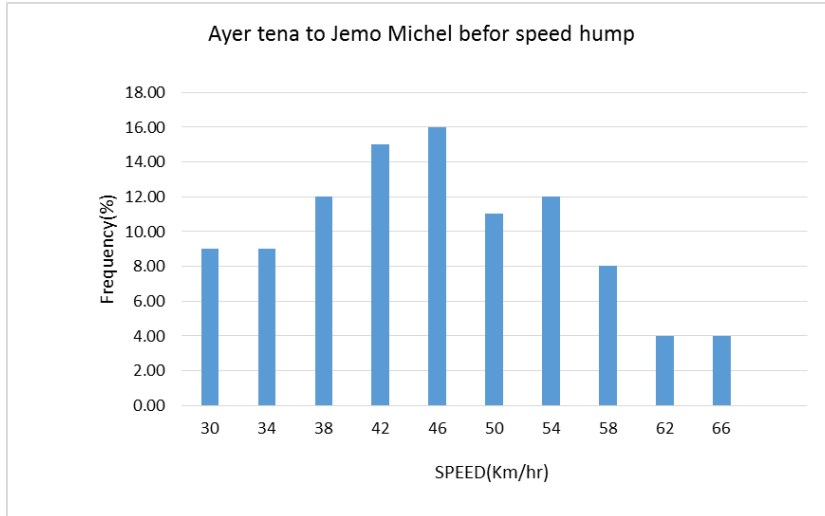


Figure E- 8 Frequency histogram before speed hump

Table E- 5 Frequency distribution table for Kara to Wesson road spot speed study before approaching the speed hump

speed class(Km/h)	class mid value(Ui)	class frequency in a class(no.of observation in a	fiui	percentage of observation in a class	cummlative percentage observation in	fi(ui-u)2	mean speed(u)	$\sqrt{\sum fi(ui-u)^2/n-1}$
21-23.5	22	4	88	4.00	4	918.09	37.15	7.2
24-26.5	25	4	100	4.00	8.00	590.49	37.15	
27-29.5	28	7	196	7.00	15.00	586.06	37.15	
30-32.5	31	11	341	11.00	26.00	416.05	37.15	
33-35.5	34	16	544	16.00	42.00	158.76	37.15	
36-38.5	37	12	444	12.00	54.00	0.27	37.15	
39-41.5	40	17	680	17.00	71.00	138.08	37.15	
42-44.5	43	15	645	15.00	86.00	513.34	37.15	
45-47.5	46	7	322	7.00	93.00	548.26	37.15	
48-50.5	49	3	147	3.00	96.00	421.27	37.15	
51-53.5	52	4	208	4.00	100.00	882.09	37.15	
		100	3715			5172.75		

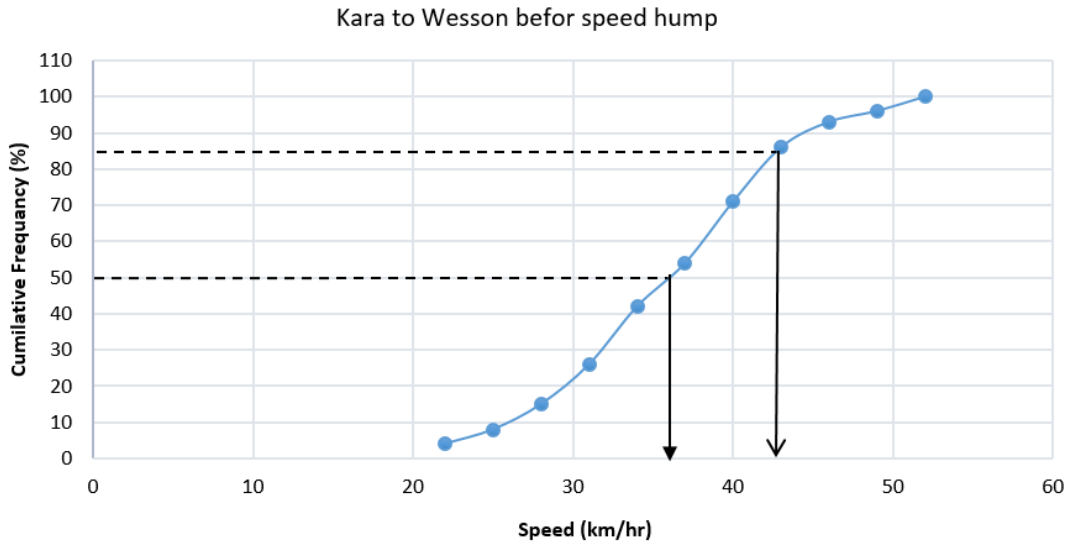


Figure E- 9 Cumulative frequency curve with 85th & 50th level marked by dotted lines before hump

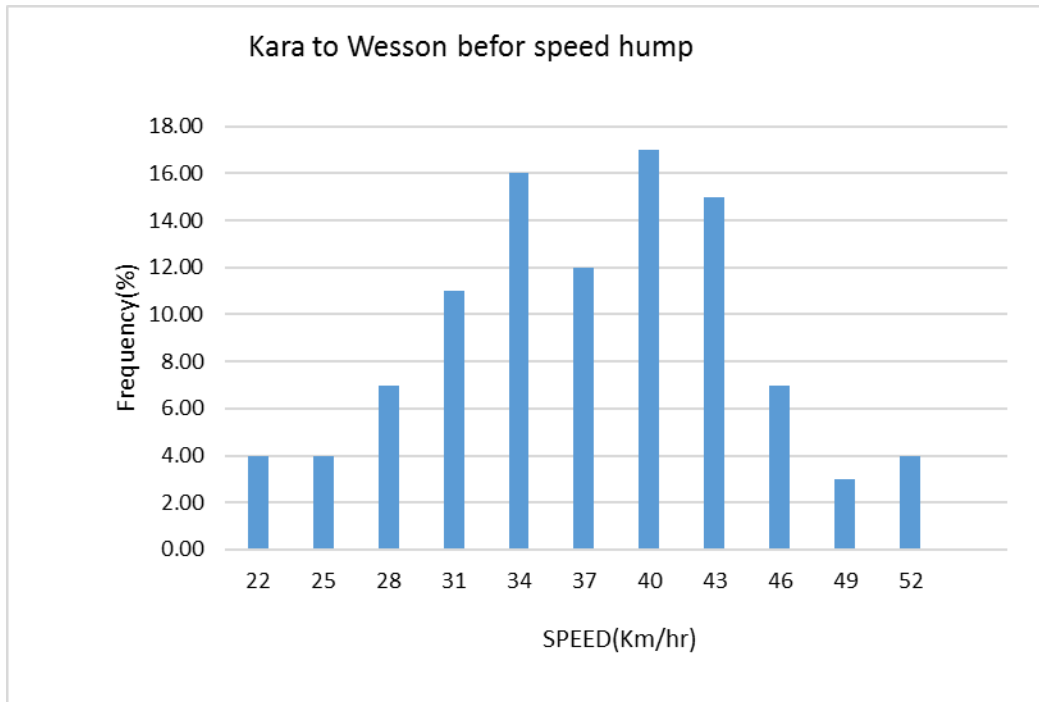


Figure E- 10 Frequency histogram before speed hump

Table E- 6 Frequency distribution table for Bisrate Gebrel to Abo round about road spot speed study before approaching the speed hump

speed class(Km/h)	class mid value(U_i)	class frequency (number observation in a class; f_i)	$f_i U_i$	percentage of observation in a class	cummlative percentage observation in aclass	$f_i(u_i-u)^2$	mean speed(u)	$\sqrt{\sum f_i(u_i-u)^2/n-1}$
20-23	22	4	88	4.00	4.00	1489.96	41.3	8.7
24-27	26	5	130	5.00	9.00	1170.45	41.3	
28-31	30	9	270	9.00	18.00	1149.21	41.3	
32-35	34	8	272	8.00	26.00	426.32	41.3	
36-39	38	16	608	16.00	42.00	174.24	41.3	
40-43	42	19	798	19.00	61.00	9.31	41.3	
44-47	46	12	552	12.00	73.00	265.08	41.3	
48-51	50	13	650	13.00	86.00	983.97	41.3	
52-55	54	11	594	11.00	97.00	1774.19	41.3	
55-57	56	3	168	3.00	100.00	648.27	41.3	
		100	4130			7442.73		

Bisrate Gebrel to Abo RA befor SH

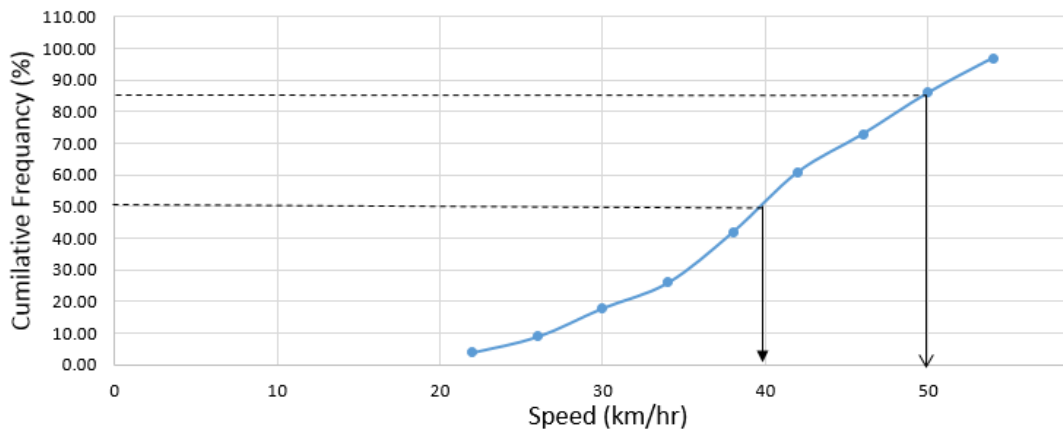


Figure E- 11 Cumulative frequency curve with 85th & 50th level marked by dotted lines before hump



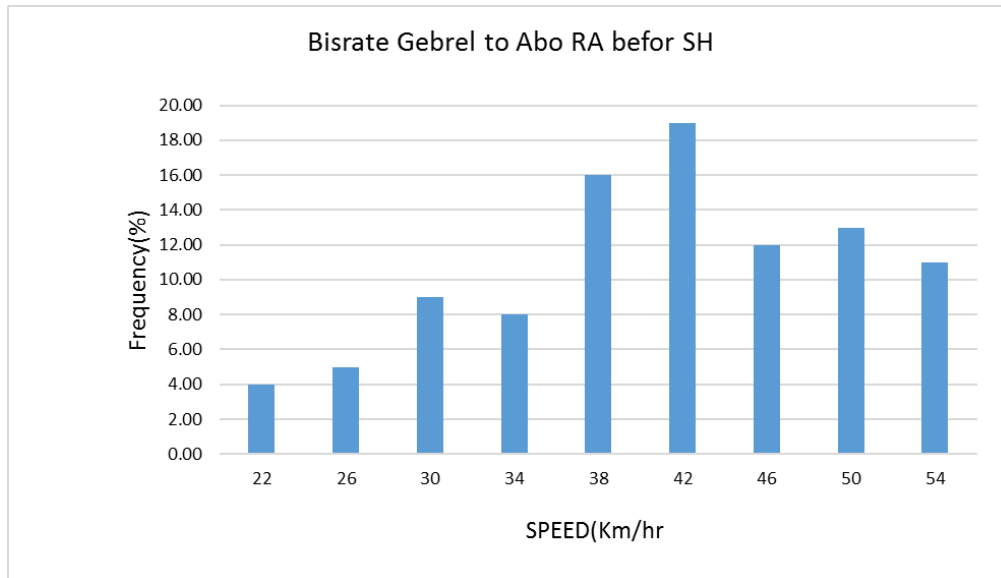


Figure E- 12 Frequency histogram before speed hump

Table E- 7 Frequency distribution table for Anjo RA to Keranyo RA about road spot speed study before approaching the speed hump

speed class(Km/h)	class mid value(Ui)	class frequency in a class(no.of observation in a class;fi)	fiui	percentage of observation in a class	cummlative perpercentage observation in aclass	fi(ui-u)2	mean speed(u)	$\sqrt{\sum fi(ui-u)^2/n-1}$
23-25.5	24	8	192	8.00	8	1157.77	36.03	6.7
26-28.5	27	8	216	8.00	16.00	652.33	36.03	
29-31.5	30	12	360	12.00	28.00	436.33	36.03	
32-34.5	33	13	429	13.00	41.00	119.35	36.03	
35-37.5	36	12	432	12.00	53.00	0.01	36.03	
38-40.5	39	18	702	18.00	71.00	158.78	36.03	
41-43.5	42	15	630	15.00	86.00	534.61	36.03	
44-46.5	45	11	495	11.00	97.00	885.07	36.03	
47-49.5	48	2	96	2.00	99.00	286.56	36.03	
50-52.5	51	1	51	1.00	100.00	224.10	36.03	
		100	3603			4454.91		



Figure E- 13 Cumulative frequency curve with 85th & 50th level marked by dotted lines before hump

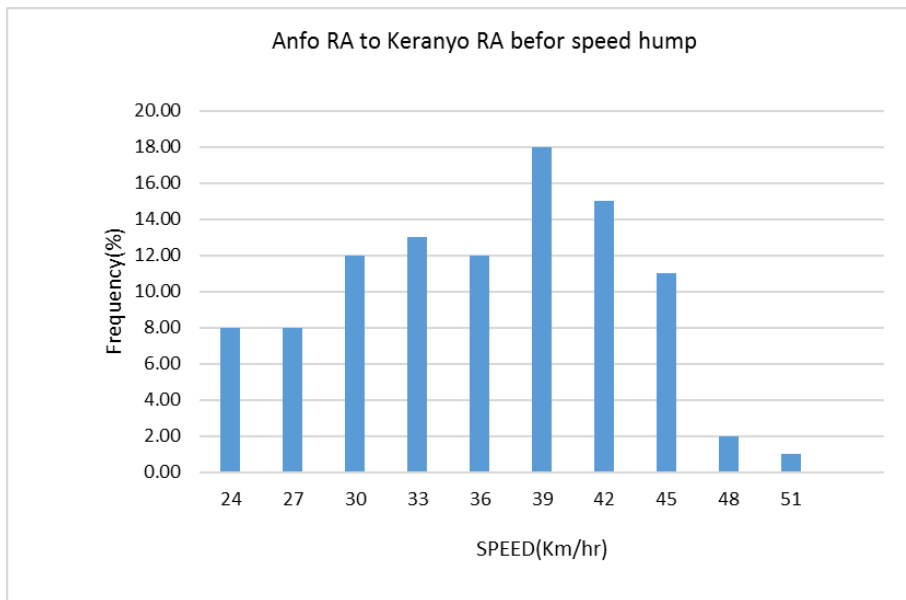


Figure E- 14 Cumulative frequency curve with 85th & 50th level marked by dotted lines before hump

APPENDEX F: Frequency distribution on speed hump

Table F- 1 Frequency distribution table for Sidest kilo to Afincho ber road spot speed study on speed hump

speed class(Km/h	class mid value(Ui)	class frequency (number observation	fiui	percentage of observation in a	cummlativepercentag e observation in	fi(ui-u)2	mean speed(u)	$\sqrt{\sum fi(ui-u)^2/n-1}$
8-9.5	9	1	9	1	1	66.59	17.16	4.20
10-11.5	11	7	77	7	8	265.62	17.16	
12-13.5	13	19	247	19	27	328.81	17.16	
14-15.5	15	21	315	21	48	97.98	17.16	
16-17.5	17	13	221	13	61	0.33	17.16	
18-19.5	19	11	209	11	72	37.24	17.16	
20-21.5	21	9	189	9	81	132.71	17.16	
22-23.5	23	14	322	14	95	477.48	17.16	
24-25.5	25	4	100	4	99	245.86	17.16	
26-27.5	27	1	27	1	100	96.83	17.16	
		100	1716	100		1749.44		

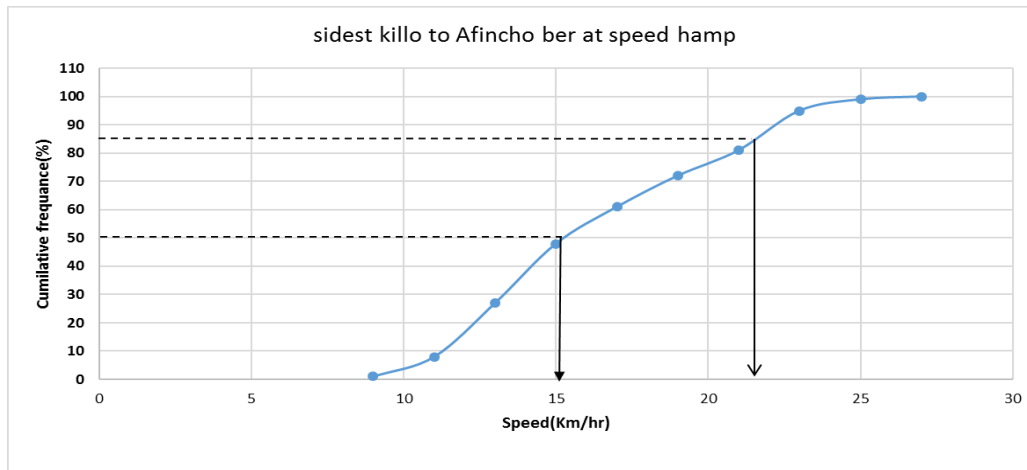


Figure F- 1 Cumulative frequency curve with 85th & 50th level marked by dotted lines on speed hump

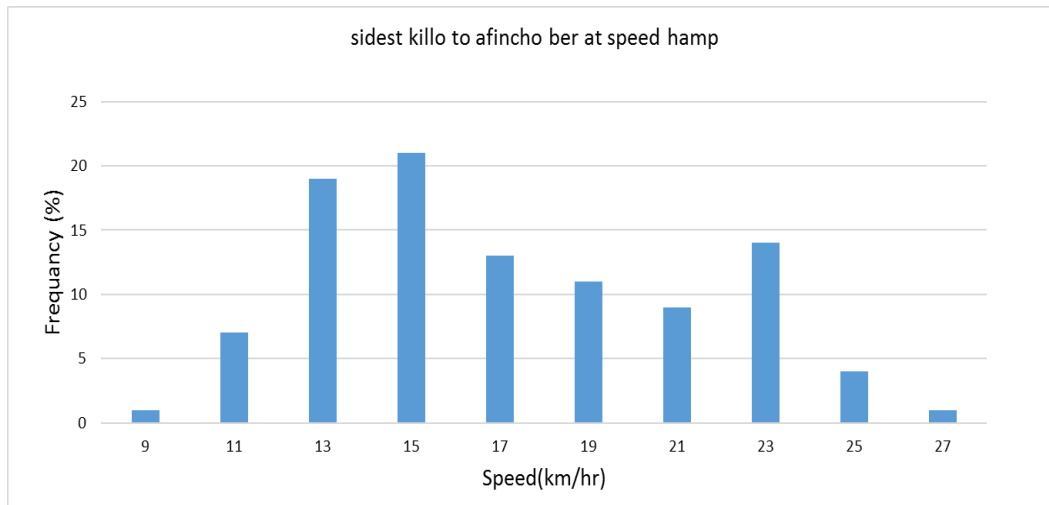


Figure F- 2 Frequency histogram on hump

Table F- 2 Frequency distribution table for Aware to Balderas road spot speed study on approaching the speed hump

speed class(Km/h)	class mid value(Ui)	class frequency (number observation in a class;fi	fiui	percentage of observation in a class	cummlativepercentage observation in aclass	fi(ui-u)2	mean speed(u)	$\sqrt{\sum fi(ui-u)^2/n-1}$
9-11	10	4	40	4	4	252.81	17.95	4.54
12-14	13	27	351	27	31	661.57	17.95	
15-17	16	16	256	16	47	60.84	17.95	
18-20	19	21	399	21	68	23.15	17.95	
21-23	22	18	396	18	86	295.25	17.95	
24-26	25	13	325	13	99	646.13	17.95	
27-29	28	1	28	1	100	101.00	17.95	
		100	1795	100	435	2040.75		

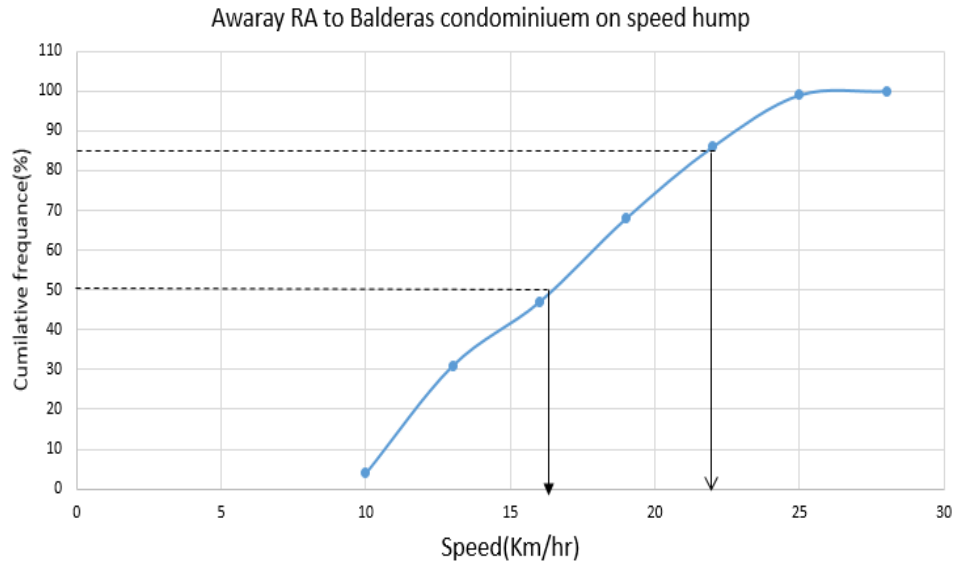


Figure F- 3 Cumulative frequency curve with 85th & 50th level marked by dotted lines on

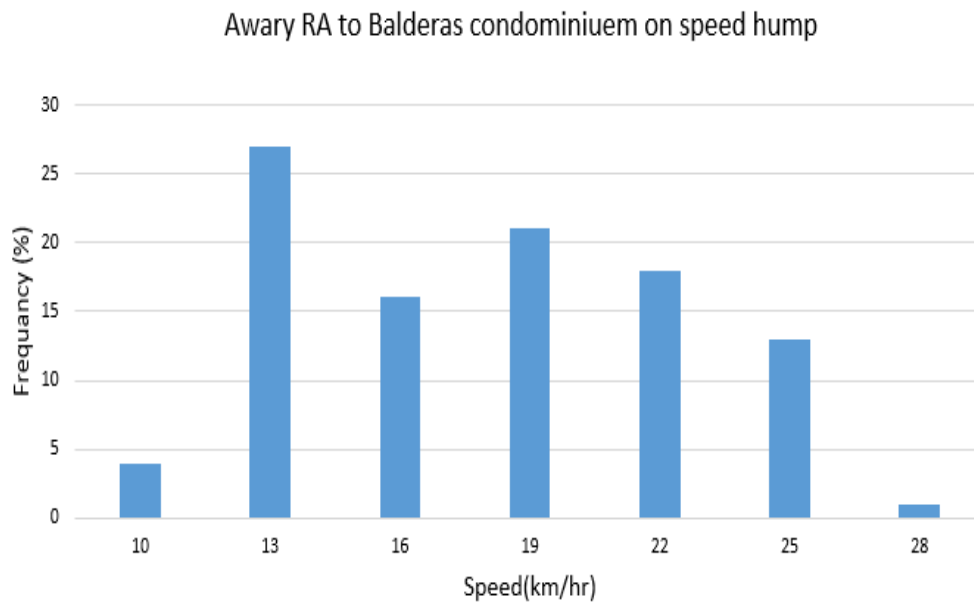


Figure F- 4 Frequency distribution table for Betel RA to keranyo RA road spot speed study on speed hump

speed class(Km/h)	class mid value(U_i)	class frequency (number observation in a class; f_i)	$f_i u_i$	percentage of observation in a class	cummlativepercentage observation in aclass	$f_i(u_i-u)^2$	mean speed(u)	$\sqrt{\sum f_i(u_i-u)^2/n-1}$
9-11	10	3	30	3.00	3.00	243.00	19	4.86
12-14	13	16	208	16.00	19.00	576.00	19	
15-17	16	25	400	25.00	44.00	225.00	19	
18-20	19	21	399	21.00	65.00	0.00	19	
21-23	22	12	264	12.00	77.00	108.00	19	
24-26	25	15	375	15.00	92.00	540.00	19	
27-29	28	8	224	8.00	100.00	648.00	19	
		100	1900	100.00	400.00	2340.00		

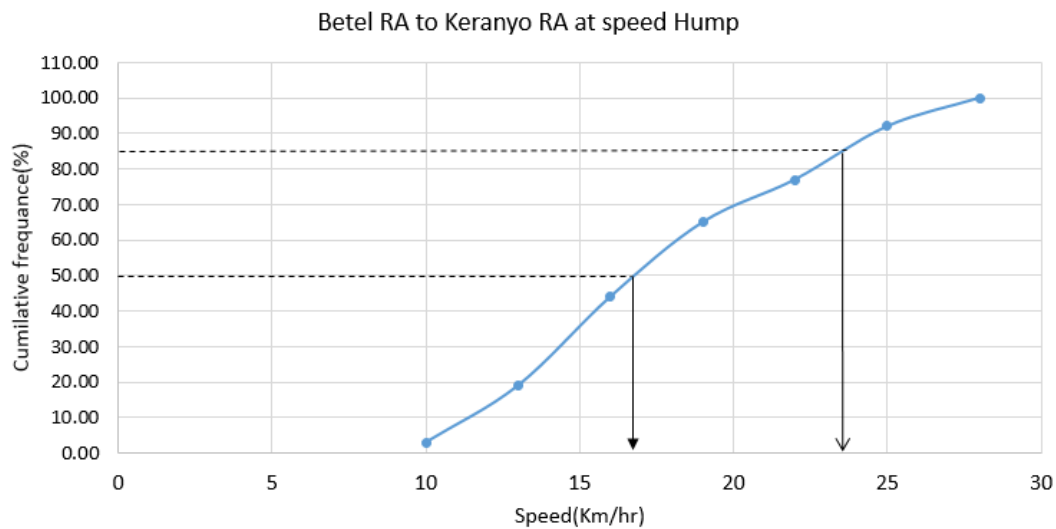


Figure F- 5 Cumulative frequency curve with 85th & 50th level marked by dotted lines on speed hump

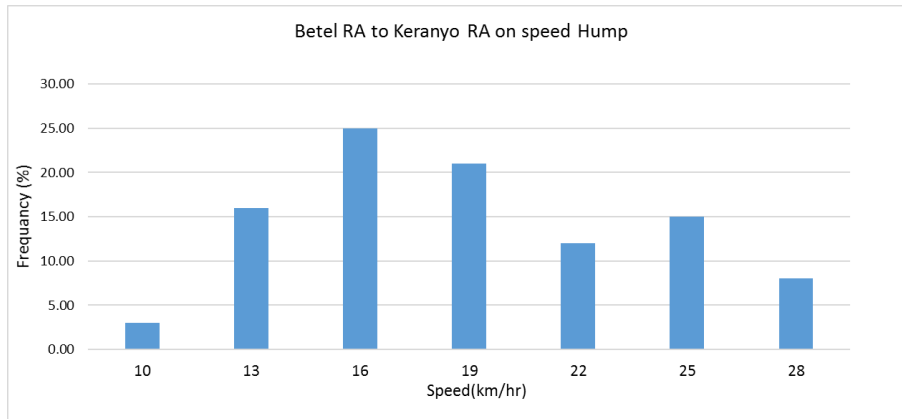


Figure F- 6 Frequency histogram on speed hump

Table F- 3 Frequency distribution table for Ayer tena to Jemo Michel road spot speed study on speed hump

speed class(Km/h)	class mid value(Ui)	class frequency (number observation in a class;fi	fiui	percentage of observation in a class	cummlativepercentage observation in aclass	fi(ui-u)2	mean speed(u)	$\sqrt{\sum fi(ui-u)^2/n-1}$
9-11	10	5	50	5	5	435.24	19.33	4.73
12-14	13	11	143	11	16	440.76	19.33	
15-17	16	21	336	21	37	232.87	19.33	
18-20	19	22	418	22	59	2.40	19.33	
21-23	22	19	418	19	78	135.45	19.33	
24-26	25	16	400	16	94	514.38	19.33	
27-29	28	6	168	6	100	451.01	19.33	
		100	1933	100	389	2212.11		

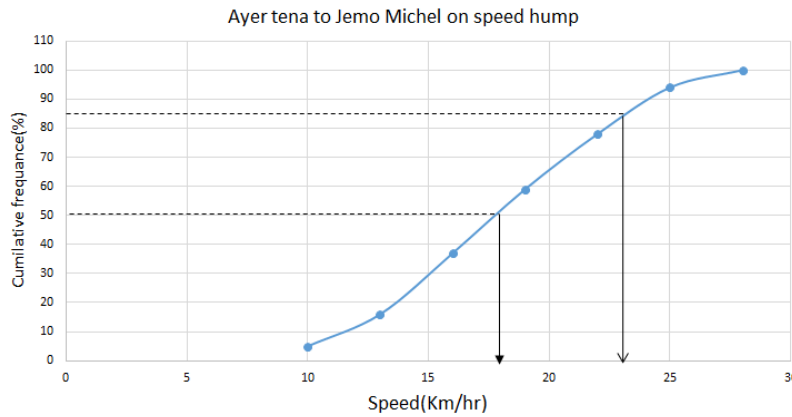


Figure F- 7 Cumulative frequency curve with 85th & 50th level marked by dotted lines on speed hump



Figure F- 8 Frequency histogram on speed hump

Table F- 4 Frequency distribution table for Kara to Wesson road spot speed study on speed hump

speed class(Km/h)	class mid value(Ui)	class frequency (number observation in a class,fi)	fiui	percentage of observation in a class	cummlativepercentage observation in aclass	fi(ui-u)2	mean speed(u)	$\sqrt{\sum fi(ui-u)^2/n-1}$
10-11.5	11	11	121	11.00	11	652.19	18.7	4.72
12-13.5	13	7	91	7.00	18.00	240.38	18.86	
14-15.5	15	13	195	13.00	31	193.69	18.86	
16-17.5	17	16	272	16.00	47	55.35	18.86	
18-19.5	19	12	228	12.00	59	0.24	18.86	
20-21.5	21	13	273	13.00	72	59.53	18.86	
22-23.5	23	12	276	12.00	84	205.68	18.86	
24-25.5	25	9	225	9.00	93	339.30	18.86	
26-27.5	27	7	189	7	100	463.82	18.86	
		100	1870	100.00	515	2210.17		



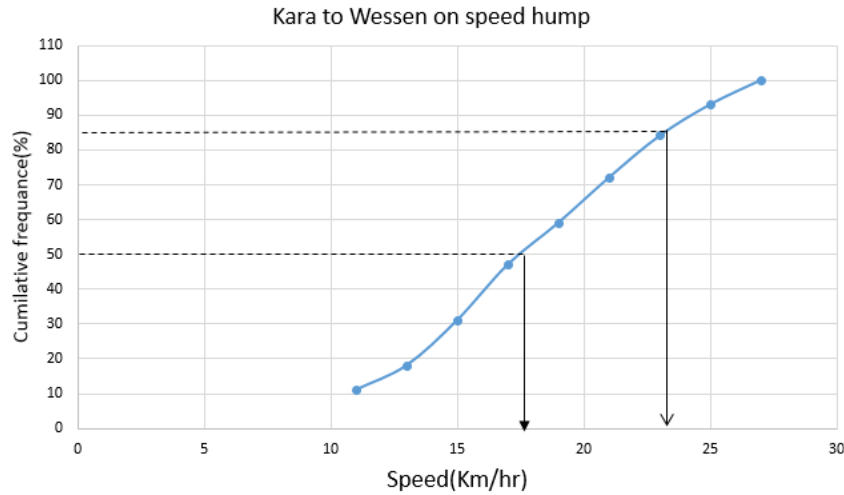


Figure F- 9 Cumulative frequency curve with 85th & 50th level marked by dotted lines on speed hump

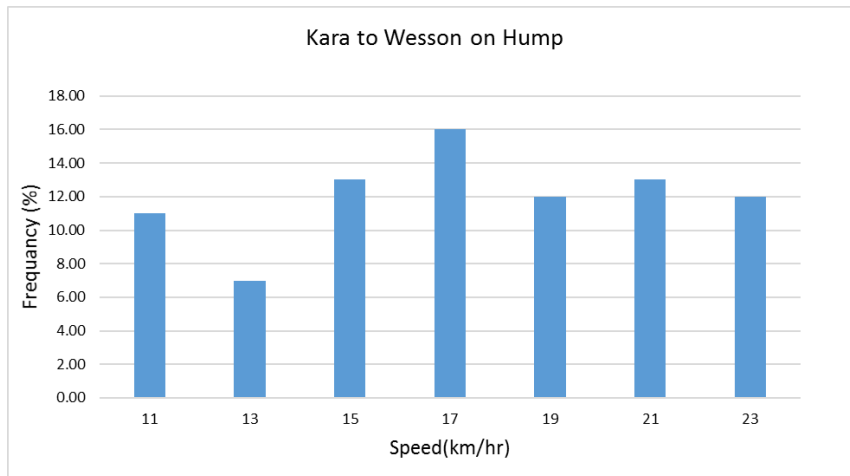


Figure F- 10 Frequency histogram on speed hump

Table F- 5 Frequency distribution table for Bisrate Gebrel to Abo RA road spot speed study on speed hump

speed class(Km/h)	class mid value(Ui)	class frequency (number observation in a class;fi	fiui	percentage of observation in a class	cummlativepercentag e observation in aclass	fi(ui-u)2	mean speed(u)	$\sqrt{\sum fi(ui-u)^2/n-1}$
10-11.5	11	11	121	11	11	505.65	17.78	4.42
12-13.5	13	13	169	13	24	297.03	17.78	
14-15.5	15	13	195	13	37	100.47	17.78	
16-17.5	17	15	255	15	52	9.13	17.78	
18-19.5	19	17	323	17	69	25.30	17.78	
20-21.5	21	12	252	12	81	124.42	17.78	
22-23.5	23	10	230	10	91	272.48	17.78	
24-25.5	25	5	125	5	96	260.64	17.78	
26-27.5	27	4	108	4	100	340.03	17.78	
		100	1778	100		1935.16		

Bisrate Gebrel to Abo RA at speed hump

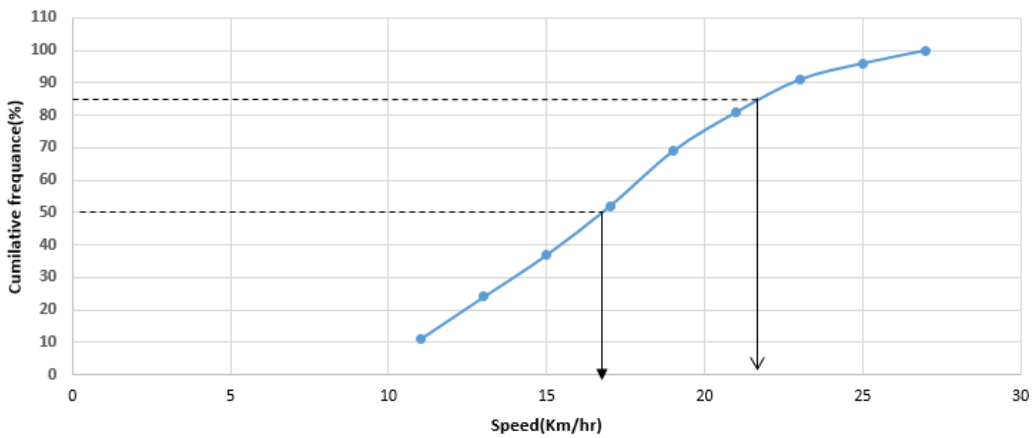


Figure F- 11 Cumulative frequency curve with 85th & 50th level marked by dotted lines on speed hump

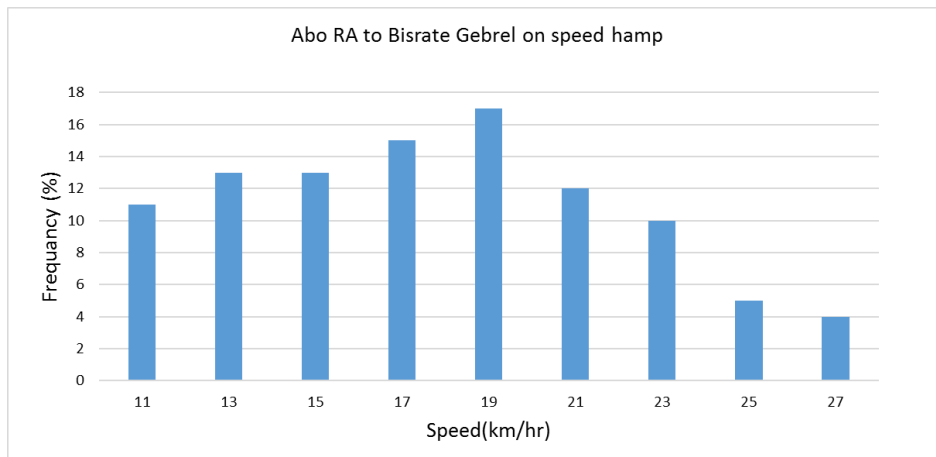


Figure F- 12 Frequency histogram on speed hump



Table F- 6 Frequency distribution table for Anfo RA to Keranyo RA road spot speed study on speed hump

speed class(Km/h)	class mid value(Ui)	class frequency (number observation in a class;fi	fiui	percentage of observation in a class	cummlativepercentage observation in aclass	fi(ui-u)2	mean speed(u)	$\sqrt{\sum fi(ui-u)^2/n-1}$
10-11.5	11	9	99	9	9	345.96	17.2	3.96
12-13.5	12	12	144	12	21	324.48	17.2	
14-15.5	15	18	270	18	39	87.12	17.2	
16-17.5	17	20	340	20	59	0.80	17.2	
18-19.5	19	15	285	15	74	48.60	17.2	
20-21.5	21	11	231	11	85	158.84	17.2	
22-23.5	23	12	276	12	97	403.68	17.2	
24-25.5	25	3	75	3	100	182.52	17.2	
		100	1720	100	484	1552.00		

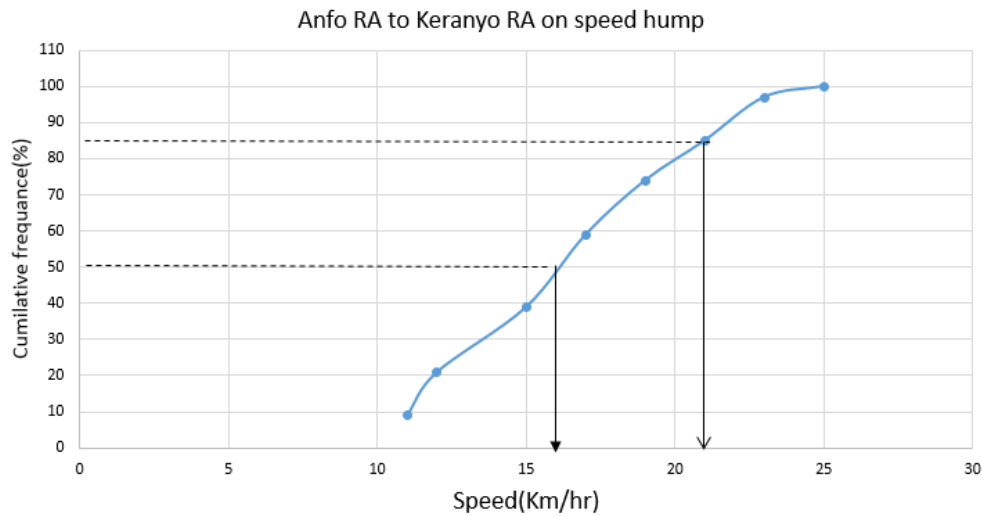


Figure F- 13 Cumulative frequency curve with 85th & 50th level marked by dotted lines on speed hump

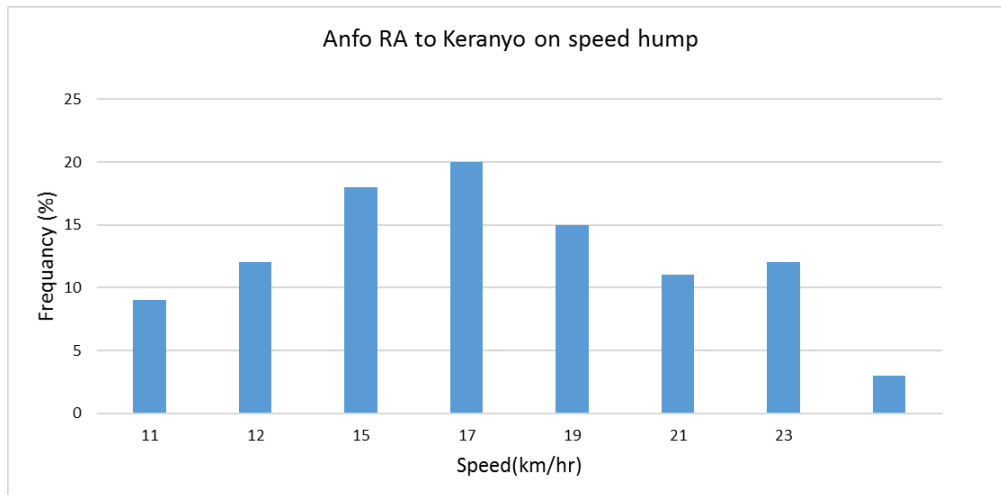


Figure F- 14 Frequency histogram on speed hump

APPENDEX G: Frequency distribution after speed hump

Table G- 1 Frequency distribution table for Sidest kilo to Afincho ber road spot speed study after speed hump

speed class(Km/h	class mid value(Ui)	class frequency (number observation in a class;fi	f _{ui}	percentage of observation in a class	cummlativepercenta ge observation in aclass	f _i (u _i -u) ²	mean speed(u)	$\sqrt{\sum f_i(u_i-u)^2/n-1}$
22-23.9	23	5	115	5	5	498.002	32.98	4.85
24-25.9	25	5	125	5	10	318.402	32.98	
26-27.9	27	7	189	7	17	250.3228	32.98	
28-29.9	29	7	203	7	24	110.8828	32.98	
30-31.9	31	14	434	14	38	54.8856	32.98	
32-33.9	33	20	660	20	58	0.008	32.98	
34-35.9	35	17	595	17	75	69.3668	32.98	
36-37.9	37	9	333	9	84	145.4436	32.98	
38-39.9	39	8	312	8	92	289.9232	32.98	
40-41.9	41	6	246	6	98	385.9224	32.98	
42-43.9	43	2	86	2	100	200.8008	32.98	
		100	3298			2323.96		



Figure G- 1 Cumulative frequency curve with 85th & 50th level marked by dotted lines after speed hump

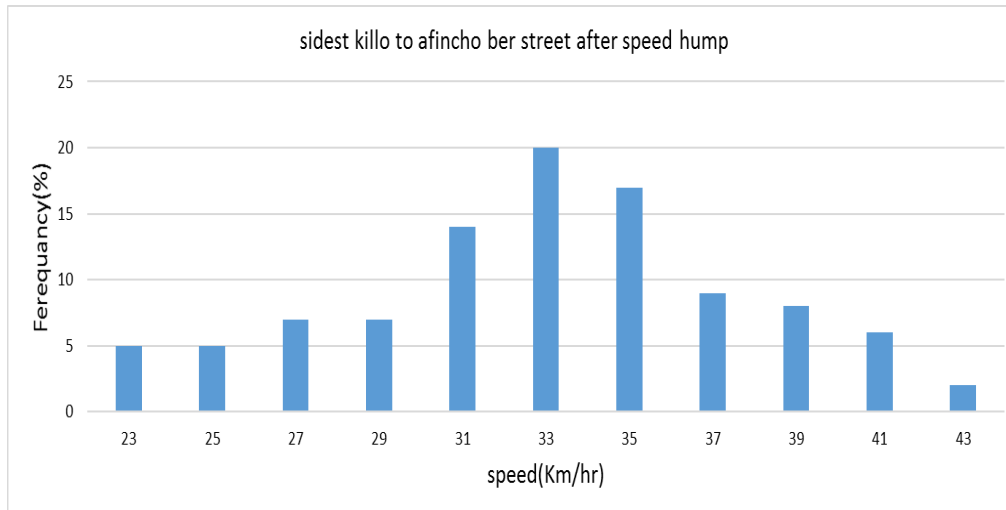


Figure G- 2 Frequency histogram after speed hump

Table G- 2 Frequency distribution table for Aware RA to Balderas condominium road spot speed study after approaching the speed hump

speed class(Km/h)	class mid value(Ui)	class frequency (number observation in a class;fi	fiui	percentage of observation in a class	cummlativepercen tage observation in aclass	fi(ui-u)2	mean speed(u)	$\sqrt{\sum fi(ui-u)^2/n-1}$
21-23	23	7	161	7	7	423.6988	30.78	4.14
24-26	25	5	125	5	12	167.042	30.78	
27-29	27	17	459	17	29	242.9028	30.78	
30-32	29	12	348	12	41	38.0208	30.78	
33-35	31	20	620	20	61	0.968	30.78	
36-38	33	14	462	14	75	68.9976	30.78	
39-41	35	13	455	13	88	231.5092	30.78	
42-44	37	10	370	10	98	386.884	30.78	
45-47	39	2	78	2	100	135.1368	30.78	
		100	3078			1695.16		

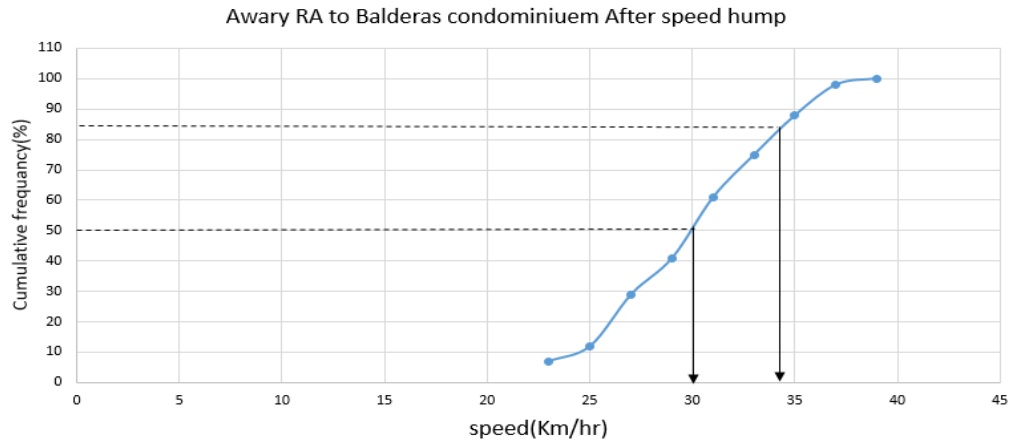


Figure G- 3 Cumulative frequency curve with 85th & 50th level marked by dotted lines after hump

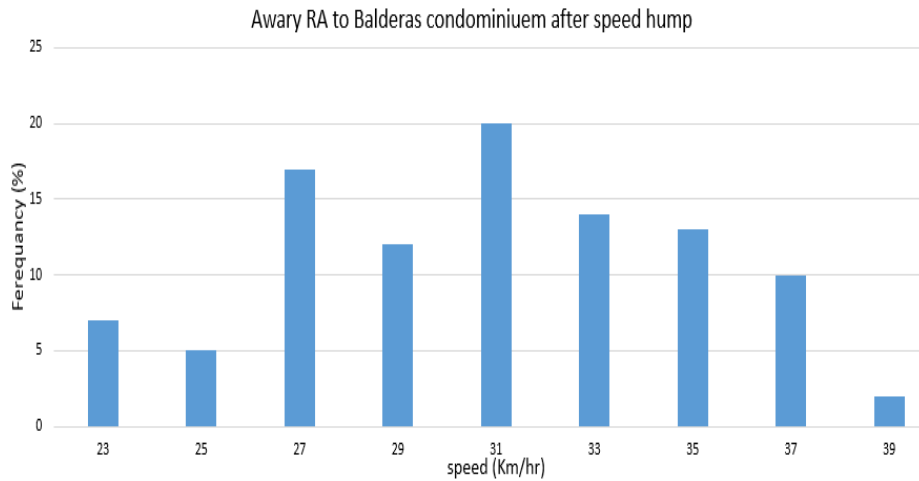


Figure G- 4 Frequency histogram after hump

Table G- 3 Frequency distribution table for Betel RA to keranyo RA to road spot speed study after speed hump

speed class(Km/h)	class mid value(Ui)	class frequency (number observation in a class;fi	fiui	percentage of observation in a class	cummlative percentage observation in aclass	fi(ui-u)2	mean speed(u)	$\sqrt{fi(ui-u)^2/n-1}$
17-18.5	18	3	54	3	3	133.07	24.66	3.32
19-20.5	20	11	220	11	14	238.87	24.66	
21-22.5	22	21	462	21	35	148.59	24.66	
23-24.5	24	16	384	16	51	6.97	24.66	
25-26.5	26	23	598	23	74	41.30	24.66	
27-28.5	28	21	588	21	95	234.27	24.66	
29-30.5	30	2	60	2	97	57.03	24.66	
31-32.5	32	1	32	1	98	53.88	24.66	
33-34.5	34	2	68	2	100	174.47	24.66	
		100	2466			1088.44		

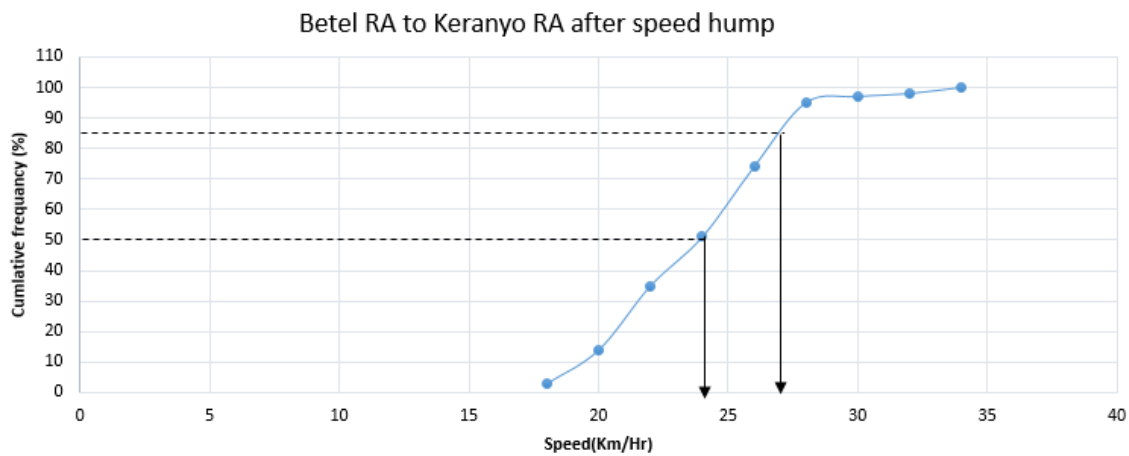


Figure G- 5 Cumulative frequency curve with 85th & 50th level marked by dotted lines after speed hump

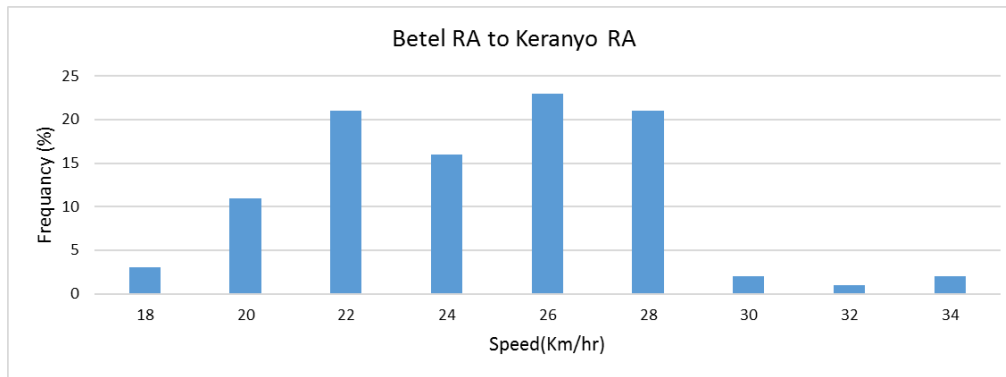


Figure G- 6 Frequency histogram after speed hump

Table G- 4 Frequency distribution table for Ayer tena to Jemo Michel road spot speed study after speed hump

speed class(Km/h)	class mid value(Ui)	class frequency (number observation in a class;fi	fiui	percentage of observation in a class	cummlativepercent age observation in aclass	fi(ui-u)2	mean speed(u)	$\sqrt{\sum fi(ui-u)^2/n-1}$
26-28	27	12	324	12	12	1407.4668	37.83	6.93
29-31	30	10	300	10	22	613.089	37.83	
32-34	33	12	396	12	34	279.9468	37.83	
35-37	36	13	468	13	47	43.5357	37.83	
38-40	39	17	663	17	64	23.2713	37.83	
41-43	42	13	546	13	77	226.0557	37.83	
44-46	45	11	495	11	88	565.4979	37.83	
47-49	48	7	336	7	95	724.0023	37.83	
50-52	51	5	255	5	100	867.2445	37.83	
		100	3783			4750.11		

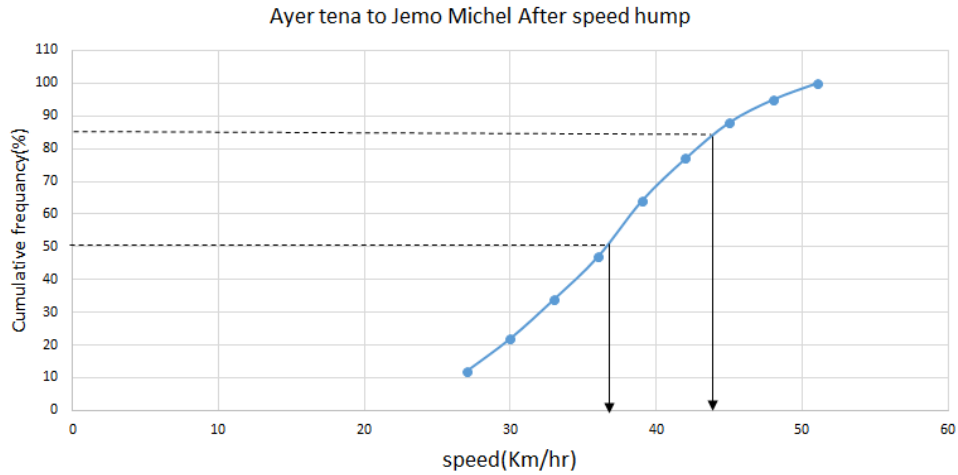


Figure G- 7 Cumulative frequency curve with 85th & 50th level marked by dotted lines after speed hump

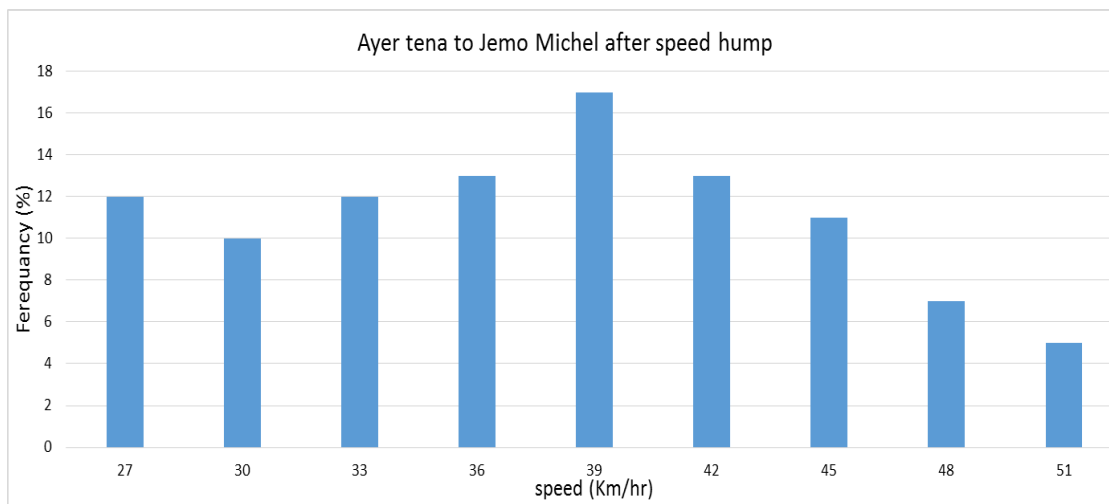


Figure G- 8 Frequency histogram after speed hump

Table G- 5 Frequency distribution table for Kara to Wesson road spot speed study after speed hump

speed class(Km/h)	class mid value(Ui)	class frequency (number observation in a class;fi	fiui	percentage of observation in a class	cummlativepercent age observation in aclass	fi(ui-u)2	mean speed(u)	$\sqrt{\sum fi(ui-u)^2/n-1}$
21-23	23	7	161	7	7	434.6608	30.88	4.42
24-26	25	8	200	8	15	267.2672	30.78	
27-29	27	13	351	13	28	185.7492	30.78	
30-32	29	15	435	15	43	47.526	30.78	
33-35	31	17	527	17	60	0.8228	30.78	
36-38	33	13	429	13	73	64.0692	30.78	
39-41	35	11	385	11	84	195.8924	30.78	
42-44	37	12	444	12	96	464.2608	30.78	
45-47	39	4	156	4	100	270.2736	30.78	
		100	3088			1930.522		

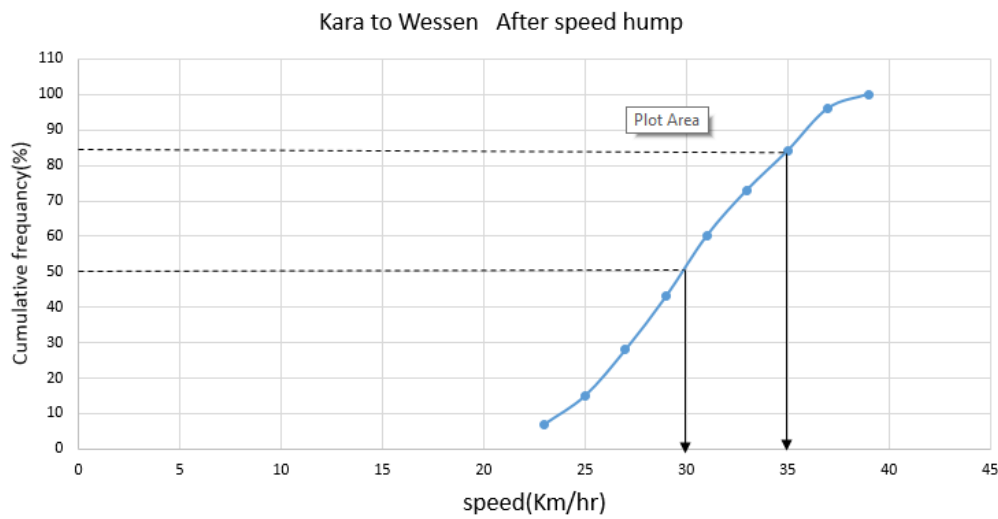


Figure G- 9 Cumulative frequency curve with 85th & 50th level marked by dotted lines after speed hump

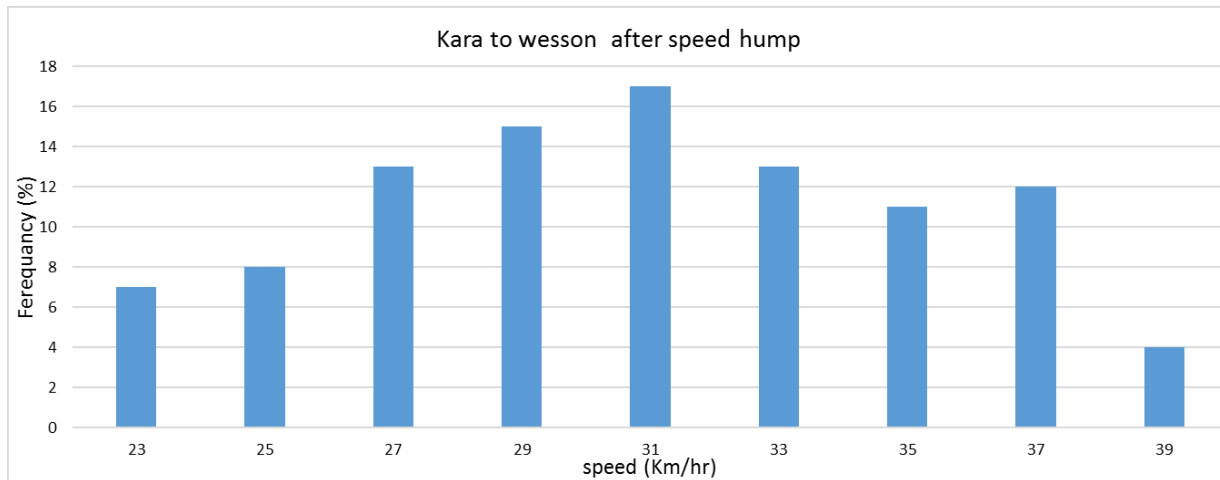


Figure G- 10 Frequency histogram after speed hump

Table G- 6 Frequency distribution table for Bisrate Gebrel to Abo RA to road spot speed study after speed hump

class mid value(Ui)	class frequency (number observation in a class;fi	f _{ui}	percentage of observation in a class	cummlativepercenta ge observation in aclass	f _{i(ui-u)} ²	mean speed(u)	$\sqrt{\sum f_i(ui-u)^2/n-1}$
25	7	175	7	7	745.5168	35.32	5.40
28	10	280	10	17	535.824	35.32	
31	14	434	14	31	261.2736	35.32	
34	17	578	17	48	29.6208	35.32	
37	17	629	17	65	47.9808	35.32	
40	26	1040	26	91	569.4624	35.32	
43	6	258	6	97	353.8944	35.32	
46	3	138	3	100	342.1872	35.32	
	100	3532			2885.76		

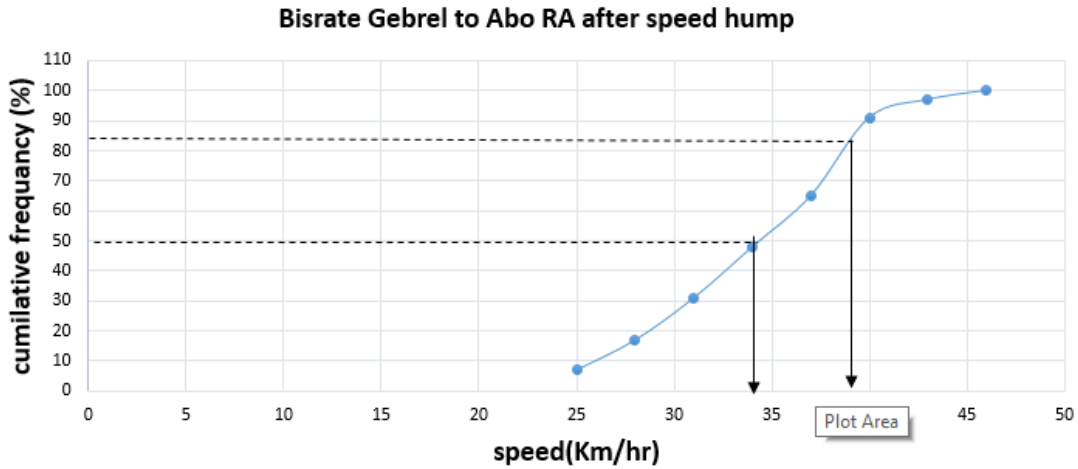


Figure G- 11 Cumulative frequency curve with 85th & 50th level marked by dotted lines after speed hump

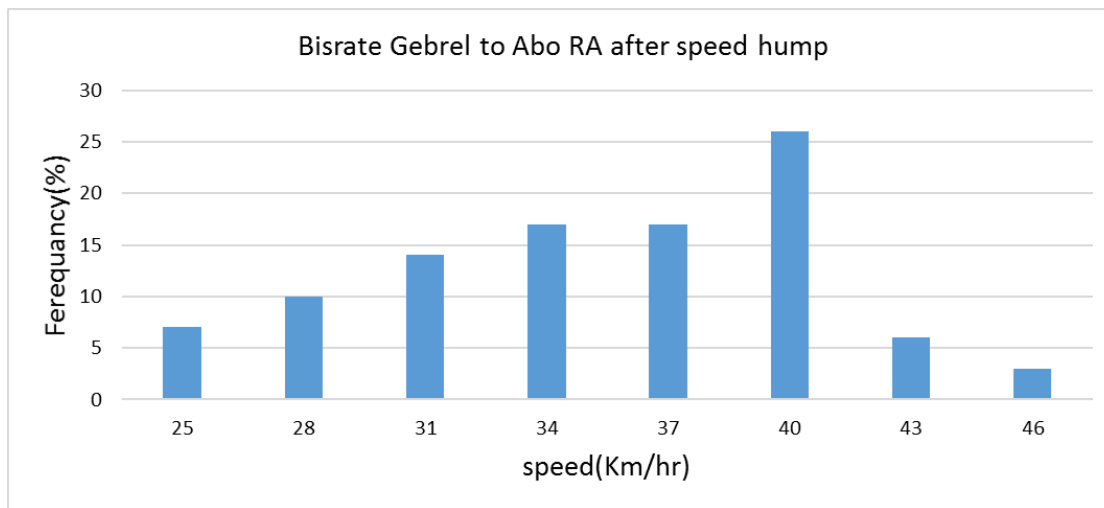


Figure G- 12 Frequency histogram after speed hump

Table G- 7 Frequency distribution table for Anfo RA to Keranyo RA to road spot speed study after speed hump

speed class(Km/h)	class mid value(U _i)	class frequency (number observation in a class;f _i)	f _i u _i	percentage of observation in a class	cummlativepercentag e observation in aclass	f _i (u _i -u) ²	mean speed(u)	$\sqrt{\sum f_i(u_i-u)^2/n-1}$
20-22	21	7	147	7	7	1008	33	6.38
23-25	24	6	144	6	13	486	33	
26-28	27	15	405	15	28	540	33	
29-31	30	13	390	13	41	117	33	
32-34	33	13	429	13	54	0	33	
35-37	36	19	684	19	73	171	33	
38-40	39	12	468	12	85	432	33	
41-43	42	14	588	14	99	1134	33	
44-46	45	1	45	1	100	144	33	
		100	3300			4032		

Anfo RA to Keranyo RA After speed hump

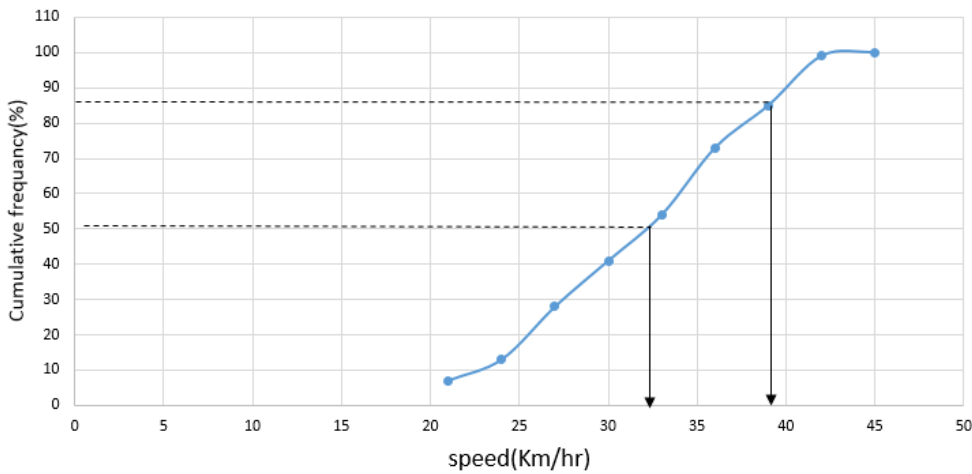


Figure G- 13 Cumulative frequency curve with 85th & 50th level marked by dotted lines after speed hump



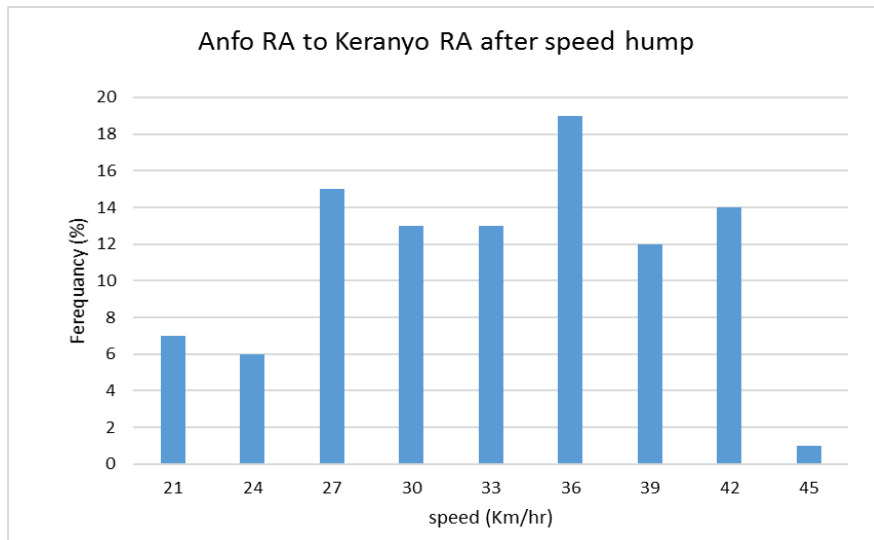


Figure G- 14 Frequency histogram after speed hump