A

Project Report

On

STUDY ON SPEED PROFILE ACROSS SPEED BUMPS

Submitted by

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(Roll No: 110CE0448)

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Bachelor of Technology

In

Civil Engineering

Under the guidance of

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CERTIFICATE

It is certified that the work contained in the thesis entitled "*Study on Speed Profile across speed bumps*" submitted by Mr. Ashish Gupta, has been carried out under my supervision and this work has not been submitted elsewhere for a degree.

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ABSTRACT:

A speeding vehicle can be a menace to other road users particularly on roads where interaction between motorized and non-motorized traffic is high, such as residential streets, school zones and community areas. Although speed limit signs are placed in accordance with the requirements of the standards, much is left to the conscience of the drivers whether they should abide by them. Hence, controlling vehicular speeds is an important issue in traffic management. The best way to influence driver speed is through traffic management. One way of controlling speed is to use static speed control devices like bumps which produces discomfort while driver experiences while crossing over it. Road bumps play a crucial role in enforcing speed limits, thereby preventing over speeding of vehicles. It significantly contributes to the overall road safety objective through the prevention of accidents that lead to death of pedestrians and damage of vehicles.

This thesis aims to present the results of a study on the performance of road bumps used in India in reducing vehicle speed. The purpose of this work is to study speed across bumps, like speed at bump, speed reduction, deceleration and acceleration by having a detailed survey of vehicular behavior near bumps of various heights. The speed profile of vehicles are determined and analyzed at various locations along the road prior to the bump, on the bump and after the bump. A critical speed change analysis has been conducted and the result presented for various vehicle category and type of bumps at various locations.

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ASHISH GUPTA

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CHAPTER -1

INTRODUCTION

1.1. BACKGROUND AND PURPOSE:-

Traffic calming measures are quite common in modern society. Traffic calming measures are physical design techniques that encourage or force motorists to drive slow and constant speed. They prevent speeding and can increase overall road safety. Traffic calming can also make streets more accessible and livable for other users such as pedestrians, cyclists and nearby residents. The main purpose of traffic calming measures is to reduce speed and create a safer traffic environment. Road bumps are one type of measures that is frequently used to reduce speed in residential areas. Traffic calming measures have to adapt to the specific condition of each location but in principle only one design of road bumps is needed. This design should lead to a comfortable crossing at speed lower than 15-20 km/h but as soon the speed increased it should be more uncomfortable to cross the road bumps. The design of ideal road bumps would make drivers hold their speed below 25 km/h at least when crossing a road bumps.

Figure 1.1 describe roughly how road bumps influence crossing speed. The designs of road bumps influences experienced driving comfort and through that drivers speed. If a road bump is designed in a way so that the driving discomfort does not increase very much as the speed increases, driver see no reason to slow down before crossing a road bump. In many cases, drivers estimate the discomfort of crossing against decrease travel time. Drivers are prepared to experience more discomfort if it will decrease their travel time, at least to some level. Road bumps are installed in different environments, on streets that have different characteristics. Car parking, interaction with vulnerable road users and other things that make up the character of a street have an effect on drivers and their speed choice.

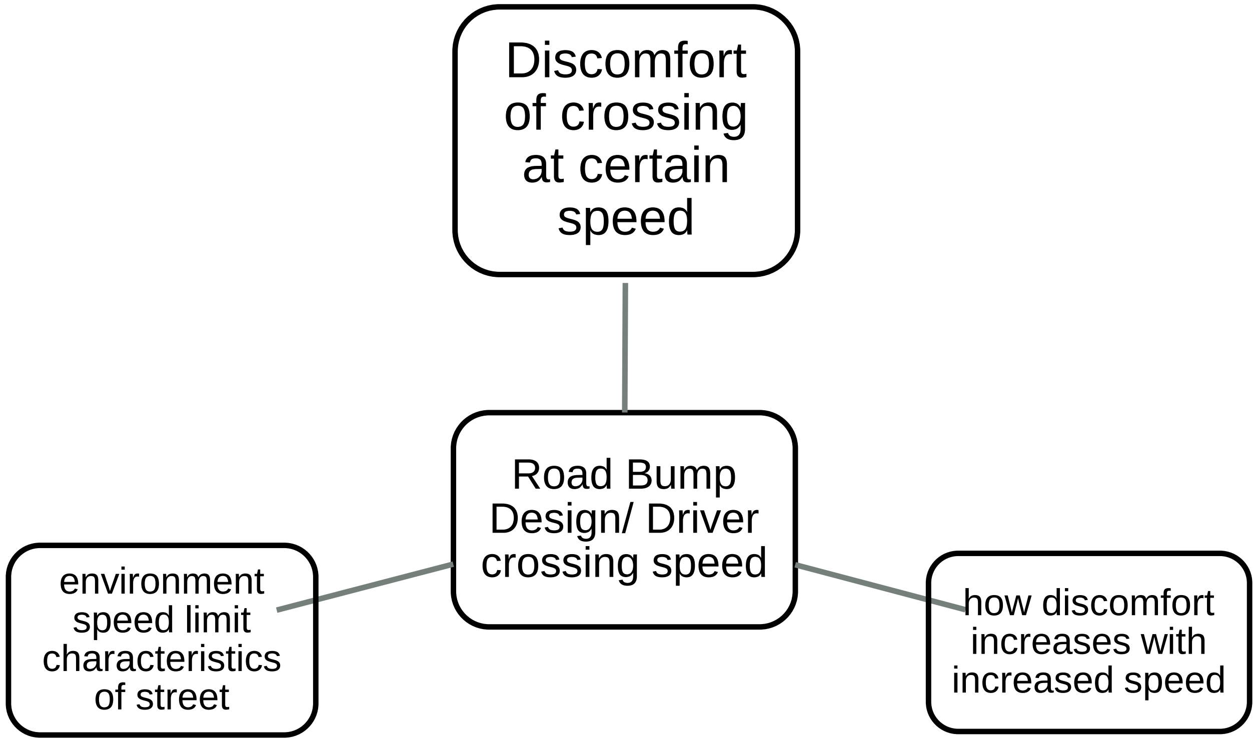

Figure 1.1

Theory about how design of road bumps influences drivers crossing speed.

A road bump is made from several different physical identities such as length, height, length of ramps etc. Physical identities control to the discomfort that road bumps produce. Vertical acceleration has been used to describe driving comfort when crossing road bumps. The connection between physical identities and characteristics of road bump is shown in figure 1.2.

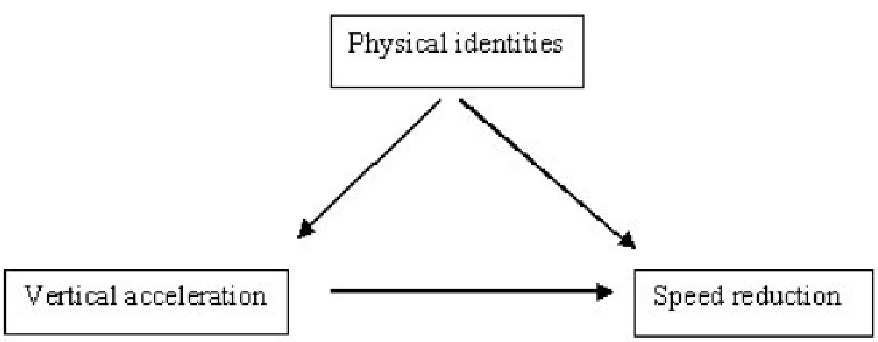

Figure 1.2 Connection between physical identities and characteristics of road humps.

1.2. ROAD BUMPS:-

Road bumps are raised pavements spanning across or partly across a roadway, thus, forcing driver to reduce the speed of their vehicles in order to minimize uncomfortable bumping or vibrating sensations produced when traversing them. A road bump works by transferring an upward force to a vehicle, and its occupants, as it crosses the bump. The force produces a front-to-back pitching acceleration in vehicles having a wheelbase similar to the length of the bump that increases as the vehicles travel faster (weber et al,1998)[4]. At low speed the acceleration is of small amplitude. As speed increase the amplitude and pitching also increase, as does the displacement. At low speeds the speed bump gently lifts and pitches the vehicle. Only as speed increase do the acceleration become more apparent as a jolt to the vehicle and its occupants.

Road bumps are designed to promote the orderly traffic moment and improve safety. However, at certain location such as approaches to manned & unmanned level crossings, sharp curves, accident prone locations, congested residential streets; control of speed may become necessary to allow smooth flow of traffic. However in an uninterrupted flow facility, with a strong emphasis on traffic safety & management, use of road bump can’t be underestimated. Road bumps, where permitted to be installed, provide visual, audible and traffic stimuli which alerts drivers and cause them to slow down. These can have different heights, base widths and shape. In fact, no particular design is suitable for all the types of vehicles using the road. They are several meters long, about a tenth of a meter high, and can cover all or a portion of the width of a roadway. A speed hump is not the same as the much wider speed bump.

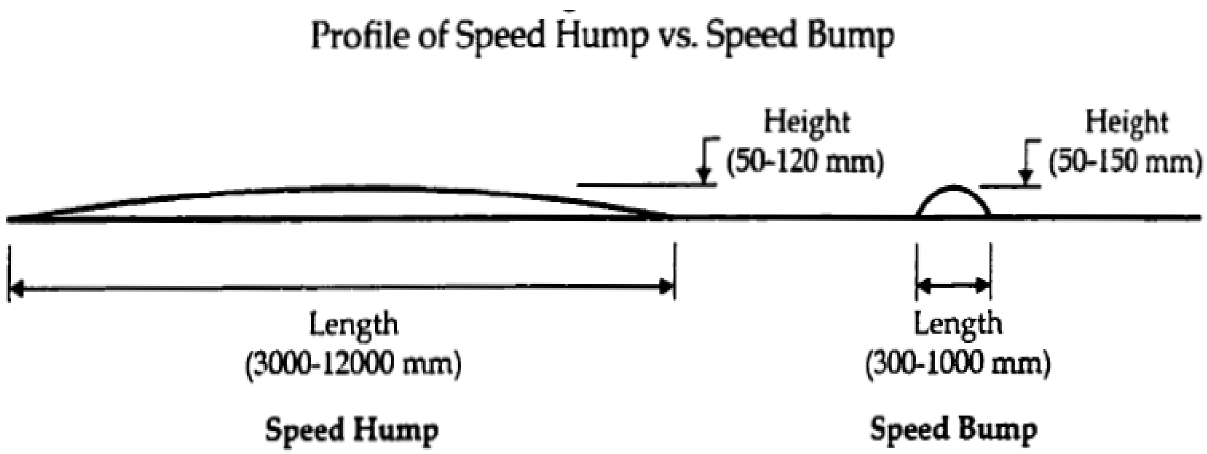

Figure 1.3[4]

Today, circular or "round top" bumps of various lengths and heights are the most common used as traffic calming measures. Other profiles such as sinusoidal and trapezoidal or "flat top" bumps have also been created. Bumps may be parabolic, circular, sinusoidal or trapezoidal in shape. Bump width may vary according to the road width (when constructed fully across the road), or to the constricted road width (when constructed partially across the road). Flat top trapezoidal bumps are particularly useful when combined with pedestrian crossing.

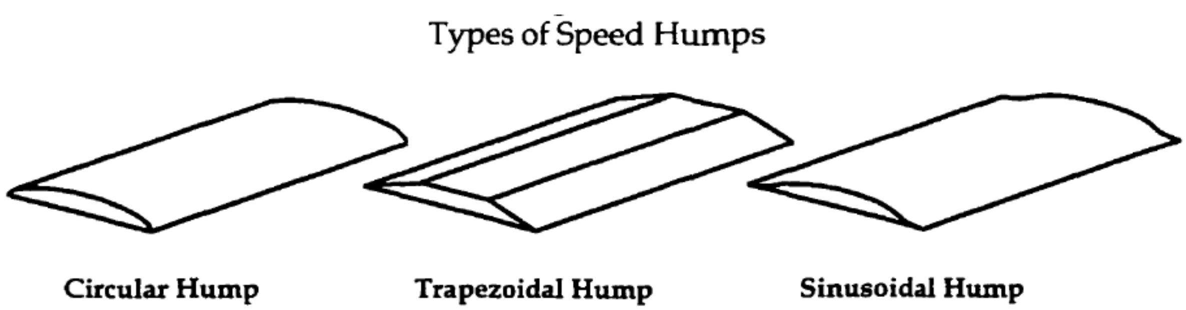

Figure 1.4 [4]

1.3. SPEED BUMP PARAMETERS:-

Speed bumps can be fully described using several geometric and layout design parameters. The geometric design parameters are Length, height, profile and width. The layout design parameters are speed bump spacing and type of materials, marking and signage.

1.3.1. LENGTH:-

Length is the most important speed bump geometric design parameter. Effective bumps should be at least as long as an automobile wheelbase to isolate the effects of entering and exiting the bumps for these vehicles. Longer speed bumps should be used if heavier vehicles are expected. Experiments have shown that as lengths are increased peak accelerations tend to occur at higher speeds, and more linear dynamic effects are created. In general, longer bumps exhibit better characteristics for speed reduction. Longer bumps may be even better suited for heavy vehicles, although upper limits have not been firmly established.

1.3.2. HEIGHT:-

Speed bump heights can influence the magnitudes of vertical accelerations and the maximum levels of perceived discomfort. High bumps, may cause damage to vehicle undermanages as they exit the measures. Low bumps can be ineffective. Heights usually range from 50 to 120 mm, with the most common being 75 or 100 mm.

1.3.3. WIDTH:-

Speed bumps can either span the entire width of a road or taper short of the curb or road edge. The advantage of the latter approach in an urban setting is that drainage at the curb and gutter is not affected, and installations are therefore less expensive. Drivers can attempt to exploit reduced widths and maneuvers around bumps unless preventative measures are taken.

1.3.4. PROFILE:-

The effects of speed bump profile, particularly the effects of varying the slopes of the entry and exit ramps, have not been examined as thoroughly as length or height. Research is ongoing to determine the optimal ramp slopes for various speed bump designs, particularly trapezoidal bumps. Circular, trapezoidal and sinusoidal speed bumps of equivalent dimensions have been found to perform about equally well, although the Dutch regard sinusoidal bumps as having the best dynamic characteristics at higher speeds.

1.3.5. SPACING:-

High bump crossing speeds can lead to high speeds between bumps, as can large distances between them. Since an objective of traffic calming is to reduce vehicle speeds over entire streets, the layout design or spacing of speed bumps is a key factor to be considered. Previous research from several countries suggests that to achieve overall speeds of 25 to 30 km/h, speed bumps should be placed between 40 and 60 meters apart. Greater spacing, up to 100 meters, can be used for speeds of 50 km/h. Bump spacing can be increased with the presence of additional traffic calming measures.

1.3.6. MATERIALS, MARKING AND SIGNAGE:-

Speed bumps with all speed reducing measures, should be highly visible to warn drivers to lower speeds and avoid vehicle damage or loss of control. This essentially eliminates the potential for any legal liability on the part of the public road authority. Most countries have developed special signs and markings for their speed bump installations, and pre-warnings, design speed signs, contrasting materials and protective bollards are usually employed.

CHAPTER 2

LITERATURE REVIEW

The literature review on road bumps encompasses a wide array of enquiries on the development of speed bump systems that can respond instantaneously to traffic conditions. Speed bumps are raised sections of roadway designed to limit the speed of motor vehicles. They are four meters long, between 76 to 100 millimeters high, and can cover all or a portion of the width of a roadway. A speed bump works by transferring an upward force to a vehicle, and its occupants, as it traverses the bump. The force induces a front-to-back pitching acceleration in vehicles. The acceleration decreases with higher speeds due to absorption of the impact by the vehicle suspension.[1] Various researches have been done on speed bump covering the criteria or the guidelines for the geometrical bump designs, optimization for the designs, effectiveness of the bump, variation of the speed over bump, factors which influence bump designs, etc.

For a bump design a definite procedure has to be followed and to have this guideline a study was done by Sahoo P.K.(2009)[2] where a computer model was developed to simulate between geometric characteristics of speed bumps and the speed of the automobiles. On the basis of the research the steps were; first select particular design 85th percentile bump-crossing speed then find out the required A/W ratio from a suitable equation then by choosing a bump shape: circular, parabolic surface profiles to be used, a bump width and compute bump height that satisfying the A/W ratio bump height is to be obtained and its permissibility is to be checked. Based on the observation obtained from the survey done, Bump-crossing speed was predicted based on area to width ratio using different geometric designs of the speed bump and the result obtained was R-Sq equals to 0.56 for two wheelers and R-Sq equals to 0.6 for passenger Cars.

Similarly Henry county, U.S. state of Georgia, has a specific henry county code[3] compromising the complete guideline for construction of speed bumps in Henry County consisting of its purpose, criteria for installation, request for study & public hearing, preparation of petition, filling of petition, no of signature required, construction of speed bump and warning posts, etc. For installation, study conducted by dept. must find that speeding problem exists on a standard 85th percentile of at least 11 miles per hour the posted speed limit. Specification of speed bump is 4inch maximum vertical rise, 22ft in horizontal length, and incline flattop-decline and maximum time allowed for installation is 3months.

The geometric roadway design proposed by Weber Philip A.(1998)[4] features the purpose of slowing traffic in residential neighborhoods. Purpose of this study was to work towards the development of speed bump design standards for Canada with posted speeds of 30-50 km/h while keeping in the mind the acceptable level of discomfort, no vehicle damage, road safety, minimizing the noise & displacement caused, and minimizing the installation & maintenance cost. Several off-road & on-road tests were carried out on existing bump & on wood made speed bumps duplicated from existing on-road speed bumps. Accelerations were recorded on a test subject and compared to discomfort criteria determined by recording speeds over existing bumps. A multiple regression model was formulated to estimate the accelerations measured using Root Sum of Squares (RSS) acceleration and optimal factorial designs were formed that produced acceleration levers equal to the discomfort criteria. From the model & optimal designs, speed bumps lengths and heights were recommended. On streets expended to carry automobile traffic only, 5.2 m by 100 mm, *7.9* m by 100 mm and *9.1* m by 75 mm speed bumps were recommended for desired speeds of *30, 40* and 50 km/h respectively. On bus routes, 6.1 m by 100 mm and *8.8* m by 100 mm speed bumps were recommended for desired speeds of 30 and 40km/h respectively.

For a speed bump, proper width has to be considered for its design as varying the width effective of the bump also. Hence a case study was done by Daniel Basil David(2012)[5] where over 1,239 vehicle speeds were recorded on total 21 Watts profile road bumps on nine residential streets in Christchurch, New Zealand. Speed data were collected using a Pro-Laser III light detection and ranging (LIDAR) speed gun. The device operating speed V_o, was taken as the 85th percentile speed of all speeds recorded across the road bumps. Regression analysis was performed to relate V_o to the bump width to road width (W_H/W_R) ratios. Two function S-curve and Power functions were selected on the basis of response variable, & predictor variable and S-curve was found out to be better fit to represent the relationship. The device operating speeds was between 21.9 km/h to 33.9 km/h with an average of 29.1 km/h with the observation; Smaller W_H/W_R ratios the more effective in producing lower speeds and the use of smaller bump widths on wide streets is more pragmatic, and it is not necessary to install narrow bumps on already narrow streets as the reduction in speed achieved is not substantially different from bumps constructed fully across the street.

While designing a speed bump, major issue faced is the optimization of speed bump with length, width, and height. One of the researches was carried out in Malaysia Residential Streets by Zainuddin Nor Izzah et al., Akram Adnan Md et al. (2012)[6] where there purpose was to develop the 85th percentile speed reduction in relation to speed bump geometric design with parameters such as bump height, length & width. The speed data was obtained from spot speed data at specified location using Pro Laser III-Laser Gun Meter Detector. The data was prepared and analyzed using Minitab v16.0. The research flow started with site selection criteria, speed bump geometric data collection, spot speed data collection, model development and model validation. After several analyses were conducted, one model with R-Sq. value of 80.6% was developed using multiple linear regressions.

Another thing to keep in mind while a bump design is the discomfort level, Khorshid E. and Alfares M.(2003)[7] used sequential quadratic programming method to find an optimum speed control bumps geometric design. The vehicle-driver system represented a mathematical model consisting of 12 degree of freedom (DOF). An optimum design method for the bump geometry was proposed to reduce the excessive shocks experienced by the drivers when crossing the bump below the speed limit, while being unpleasant when going over the speed limit.

The major concern while installing the speed bumps is the effectiveness in controlling the speed of the vehicles passing over it. To check the effectiveness Ponnaluri Raj V, And Groce Paul W.(2005)[8] conducted a survey by having the speed variation before and after the installation of the speed bumps i.e. this case study features the description for collection and evaluation of comparison pre- and post-installation traffic volume and speed measures. The study segment was Dorman Road in Polk County, central Florida about 2,600 feet long consisting of 5 bumps having a speed limit of 25mph. Speed data were collected in 15-minute increments over a consecutive 2 weekdays. The pre- & post-installation data were collected one month before & after deployment of speed bumps. Traffic volume percentage distributions charts were prepared and from several iterations it was found that third degree regression model provided the best fit by comparing it with the R^2 values. R^2 values indicating the efficiency of bumps in achieving the increased consistency of travel behavior was obtained to be 0.89 & .86 for pre- & pro-installation.

However, lot of concerns has been voiced about speed bumps, particularly their effectiveness and their potential to create unwanted noise and vibration. Various studies have been carried out and one them was the study in the Netherlands and Australia carried by Zaidel D. et al.(1992)[9] where they have shown that well-designed speed bumps produce very low levels of unwanted noise and little vibrations except on passing vehicles. Impact to adjacent buildings or individuals has been negligible.

Once the speed bumps are constructed proper maintenance and traffic signing is also required, so Tchemou Gilbert et al.(2012)[10] conducted a study on the critical speed bumps built throughout the triangle Yaounde-Douala-Yaounde-Bafoussam regarding the problems faced both in terms of design materials used, and the location of traffic signing. The basic intension was to draw the attention of the authority regarding the problem faced due to improper maintenance in speed bumps. Study was done by traversing the triangle and collecting the field data to identify each retarder by its location, type, geometry. In this study, 310 speed bumps were identified basically of four types: soundtrack, speed bumps, trapezoidal and tray. Out of which 288 had problems of material design and signaling. Over 50% of asphalt concrete materials were either collapsed or the road to the launch of these is padded. Over 70% was not up to the respective standard dimensions. 62% of the problems with speed bumps were due either to the absence of signs or bad signs.

CHAPTER 3:

PRESENT STUDY

3.1. METHOD ADOPTED:-

- 10m distance was considered on both left and right hand side of the bump with different marking at 10m, 7m, 5m and 2m on left and 3m, 5m, 8m, and 10m on right.
- Vehicles speed were measured at the different marking on the road using the radar gun.
- Two radar gun was used and distance between two consecutive readings by a particular radar gun was kept 5m apart.
- marking distance for 1st radar gun was -10,-5,0,5,10 and the 2nd radar gun was -7,-2,3,8.
- For each site 20 vehicles reading were noted across the 20m range.

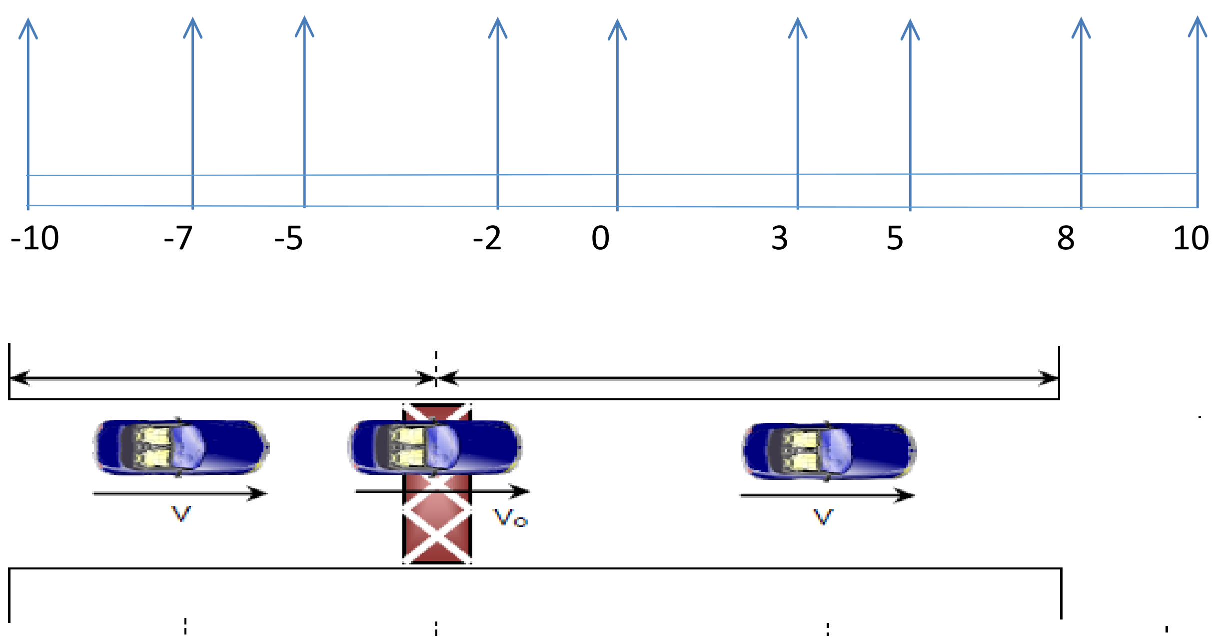

Figure 2. Vehicle across a bump

3.2. RADAR GUN:-

A radar gun is a device used to measure the speed of moving objects which may be hand-held, vehicle-mounted or static. It measures the speed of the objects at which it is pointed by detecting a change in frequency of the returned radar signal caused by the **Doppler Effect**. The radar unit used had a transmitter which operates on the K-band or a frequency of 24.125 GHz. The transmitter which of the radar sends out a sinusoidal wave. When the signal reflects off a moving target, the reflected signal's frequency is sifted proportional to the target speed according to the Doppler shift principle.

3.2.1. WORKING OF RADAR GUN:-

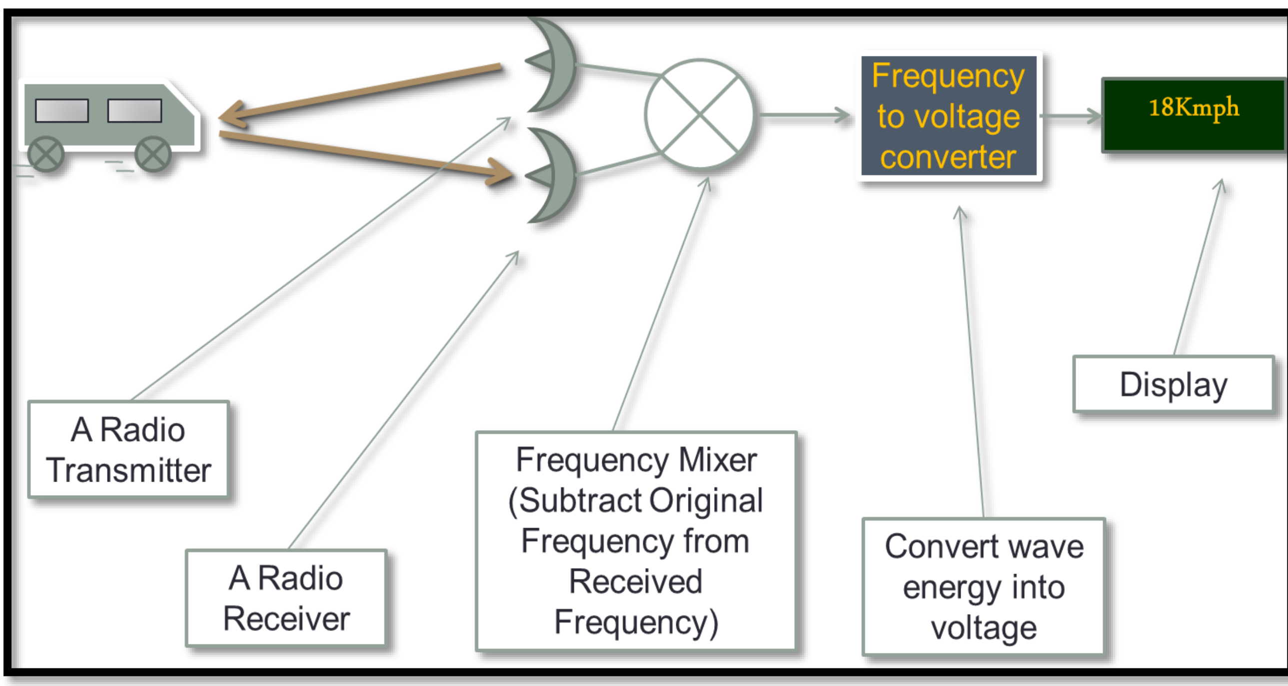

Figure 3. Working Of Radar gun

3.3. DOPPLER EFFECT:-

The Doppler effect(or Doppler shift), named after the Austrian physicist Christian Doppler, who proposed it in 1842 in Prague, is the change in frequency of a wave (or other periodic event) for an observer moving to its source. Just like whistle of train, sounded at high pitch when approaching and at low pitch while going away from the source.

- Shift in frequency $f_d=2f_0v/c$
  Where f_0: the transmitter frequency,
  v: target speed,
  c: speed of light
- Therefore target speed $v=c*f_d/2*f_0$

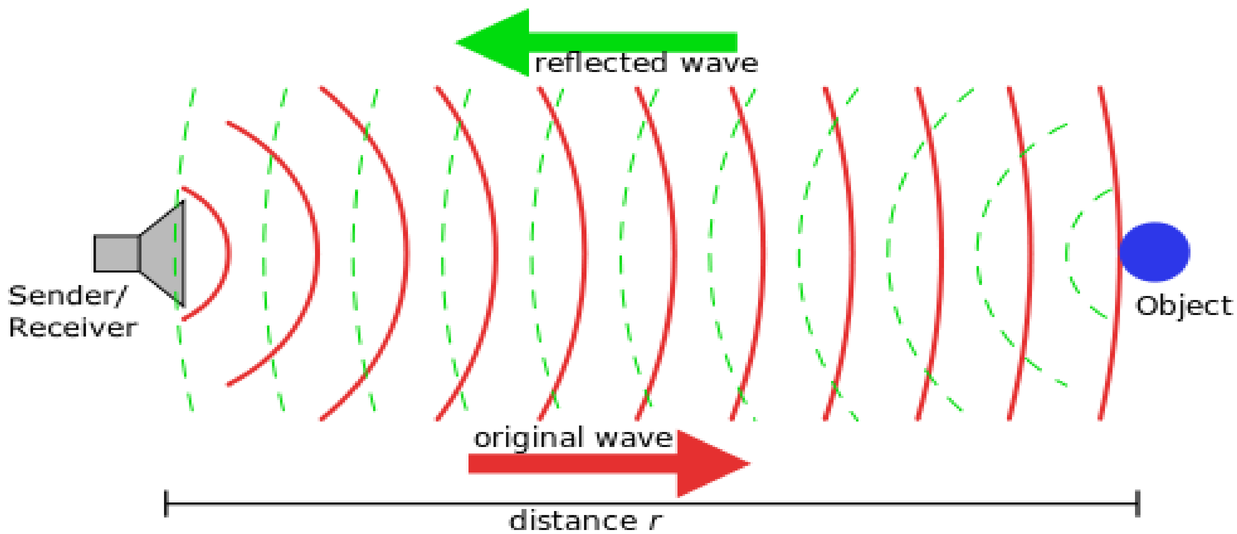

Figure 4. Principle of Doppler Effect

3.4. DATA COLLECTION SITE:-

- Three cities were selected for the collection of data: Rourkela, Cuttack, and Kolkata.
- In Rourkela 3 location of bump height of 75mm where selected i.e. sector-2, sector-17 and uditnagar.
- For all the 3 location speed variation of 4-wheelers were done including at uditnagar speed variation of 2-wheelers was also done.
- In Cuttack 2 location of bump height 100mm were selected i.e. at ring road and NH-5 from Cuttack toward Jajpur.
- For both location speed variation of 4-wheelers were done including study of 2-wheelers at ring road and study of vehicles >4-wheelers at NH-5 was done.
- In Kolkata 3 location of bump height 100mm were selected i.e. at Jadavpur, Bawanipur, and parking lot of an apartment near south-city mall.
- For location at jadavpur study of buses was done whereas for other location study of 4-wheelers were done.

CHAPTER 4:

RESULTS AND OBSERVATIONS

4.1. DATA COLLECTED:-

Table 1. Data collected

distance	**-10**	**-7**	**-5**	**-2**	**0**	**3**	**5**	**8**	**10**	**reduction**
rkl uditnagar bike=75mm	34.9	30	24.3	18.6	13.8	15.5	17.4	20.1	23.4	60.4
cuttack(ring road bike)=100mm	34.7	29.1	23.3	18	13.2	15	17.3	20.3	23.9	62.05
hwh(jadavpur=bus)=100mm	22.5	18.4	15.3	11.9	11	11.9	14.4	16.8	20.2	51
ctc jajpur nh-5>4wheelers=100mm	30.2	24.5	18.9	14.8	11.3	13.5	15.8	18.7	22.5	62.75
hwh(apartment=car)=100mm	28	23.4	18.7	14.8	11.6	14.1	15.5	17.7	19.9	58.68
hwh(bhawanipur=taxi)=100mm	33.7	28.1	22.1	16.9	12.6	14.8	16.2	19.2	22.8	62.61
ctc ring road car=100mm	37.9	31.1	24.1	17.6	12.7	15	17.4	21.4	25.1	66.58
ctc jajpur nh-5=4 wheelers=100mm	40.1	32.8	24.8	17.6	12.8	15.1	17.7	20.9	25.1	68.04
rkl(sector-2)=75mm	25.8	21.9	18.1	15.1	12	14.5	16.8	18.6	20.6	53.68
rkl (sector-17)=75mm	28.5	23.5	18.9	15.2	12.1	14.3	16.8	19.3	22.5	57.54
rkl uditnagar=75mm	31.6	26.2	21	16.2	12.5	14.7	16	18.4	21.2	60.44
avg	31.6	26.3	20.8	16	12.3	14.4	16.5	19.2	22.5	61.06

4.2. Average Speed Profile:-

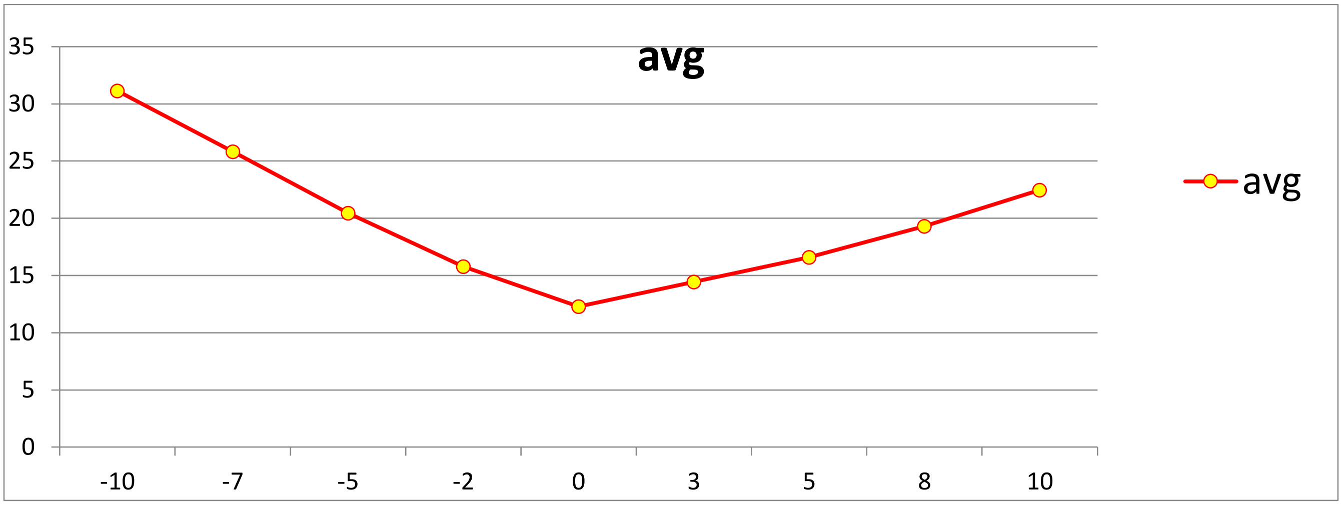

Figure 5. Average speed profile

- For vehicles across bump the speed reduction at bump is 61.06% whereas at 10 m distance from bump its 28.8%.

4.3. SPEED REDUCTION DUE TO BUMPS:-

Speed reduction is the factor or percentage with which the vehicle speed has been reduced from its approaching speed i.e. speed from the distance of 10m away from the bump.

4.3.1. Reduction due to bump height w.r.t vehicles:

Table 2. Reduction due to bump height

BUMP HEIGHT	TYPE OF VEHICLES	REDUCTION AT THE BUMP (in %)	REDUCTION AT 10m AWAY FROM BUMP (in %)
100mm	4-wheelers	69.93	33.46
75mm		57.02	25.15
100mm	2-wheelers	62.01	31
75mm		60.42	33

4.3.2. Reduction due to the type of vehicles:

Table 3. Reduction due to type of vehicles

TYPE OF VEHICLES	REDUCTION AT THE BUMP (in %)	REDUCTION AT 10m AWAY FROM BUMP (in %)
4-wheelers	61.79	30.3
2-wheelers	61.23	32.01
>4-wheelers	57.74	19.09

4.3.2. Reduction at various locations:

Table 4. Reduction due to various locations

LOCATION	REDUCTION AT THE BUMP (in %)	REDUCTION AT 10m AWAY FROM BUMP (in %)
Cuttack	67.33	35.56
Rourkela	57.45	25.15
Kolkata	60.83	30.82

4.3.3 DISTRIBUTION OF VEHICLES AGAINST SPEED REDUCTION:

Cumulative distribution of the vehicles for the different reduction in speed in term of percentage w.r.t to the approaching speed at the distance of 10m from the bump is shown in figure 6. Almost over 80% of vehicles speed was reduction by 65% w.r.t to their approaching speed.

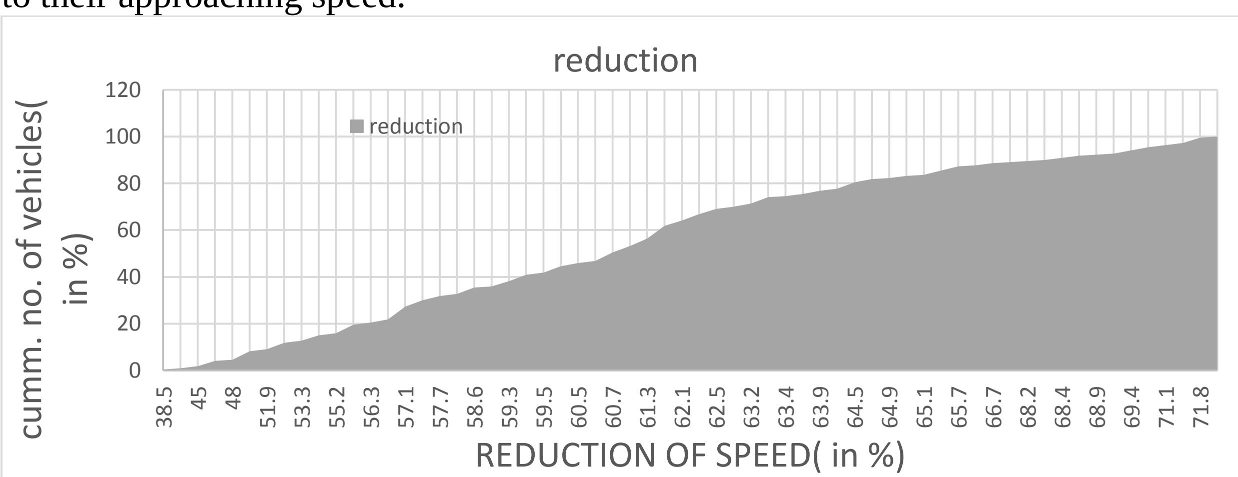

Figure 6. Distribution of vehicles against speed reduction across bumps.

4.4. GRAPHICAL COMPARISIONS:-

4.4.1. FOR 4-wheelers comparison with bump height:

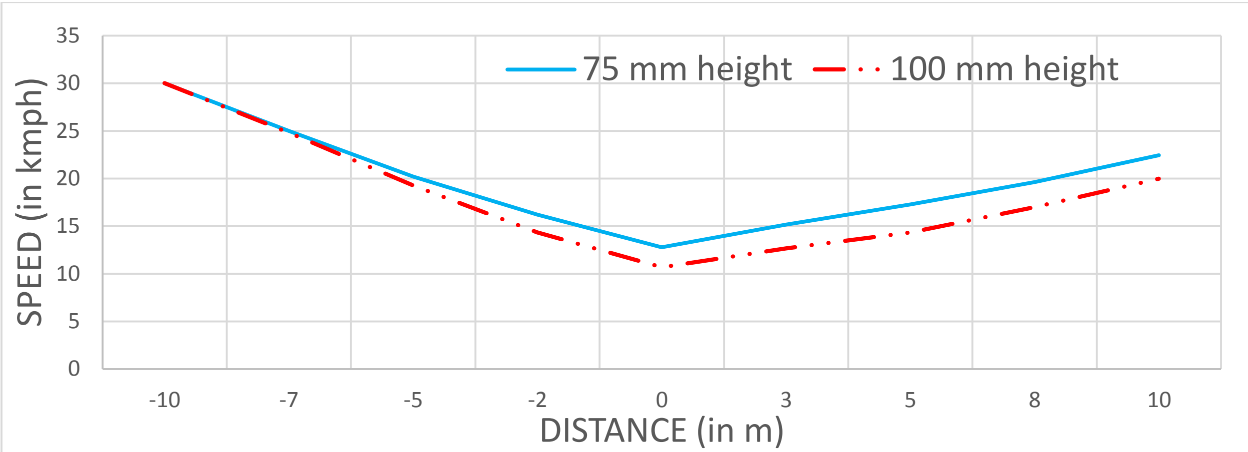

Figure 7. Reduction due to bump height for 4-wheelers

- For cars across 100 mm height bump the speed reduction at bump is 63.93% whereas 75 mm height bump its 57.02%.
- For cars 100 mm height bump the speed reduction at distance 10m is 33.46% whereas 75 mm height bump its 25.15%.

4.4.2. FOR bikes comparison with bump height:

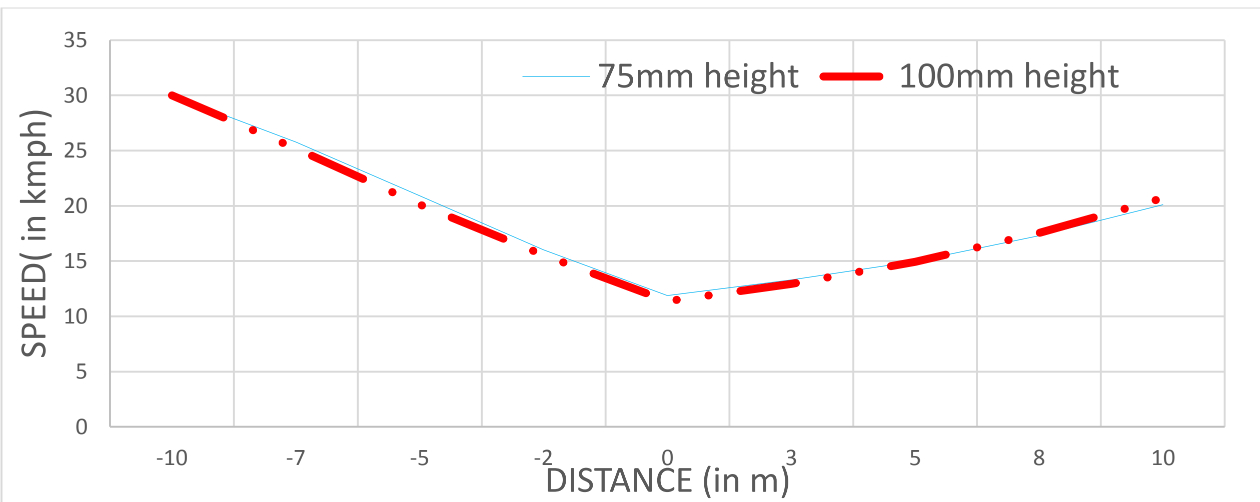

Figure 8. Reduction due to bump height for 2-wheelers

- For bikes across 100 mm height bump the speed reduction at bump is 62.01% whereas 75 mm height bump its 60.42%.
- For bikes across 100 mm height bump the speed reduction at distance 10m is 31% whereas 75 mm height bump its 33%.

4.4.3. FOR comparison between 4-wheelers and bikes:

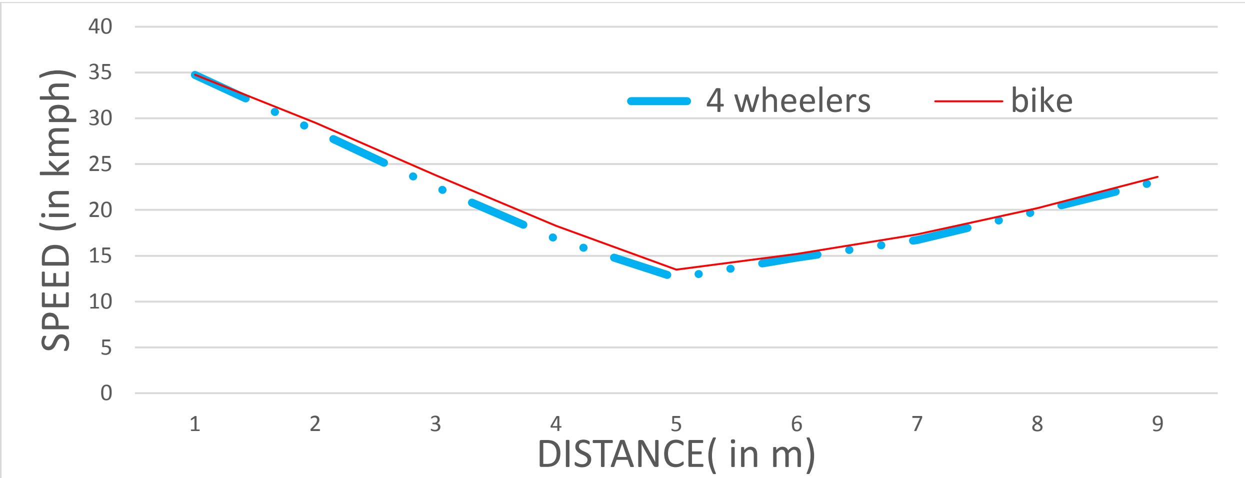

Figure 9. Reduction due to 2 and 4-wheelers

- For cars across bump the speed reduction at bump is 63.78% whereas for bikes its 61.22%.
- For cars across bump the speed reduction at distance 10m is 33% whereas for bikes its 32%.

4.4.4. FOR comparison between 4-wheelers and vehicles> 4-wheelers:

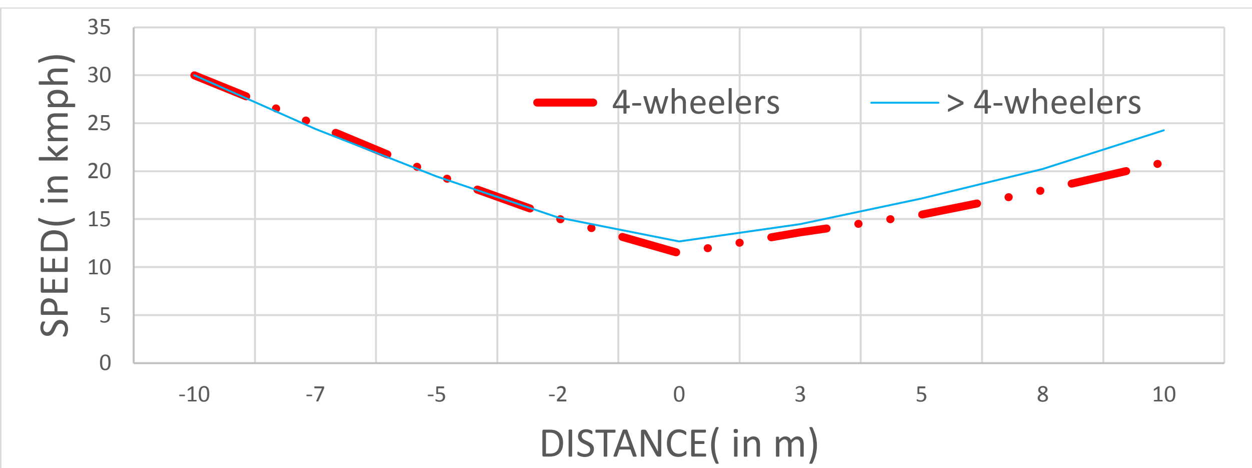

Figure 10. Reduction due to 4 and >4-wheelers

- For vehicles > 4wheelers across bump the speed reduction at bump is 57.74% whereas for 4-wheelers its 61.79%.
- For vehicles > 4wheelers across bump the speed reduction at distance 10m is 19.09% whereas for 4-wheelers its 30.3%.

4.4.5. FOR comparison between bikes and vehicles> 4-wheelers:

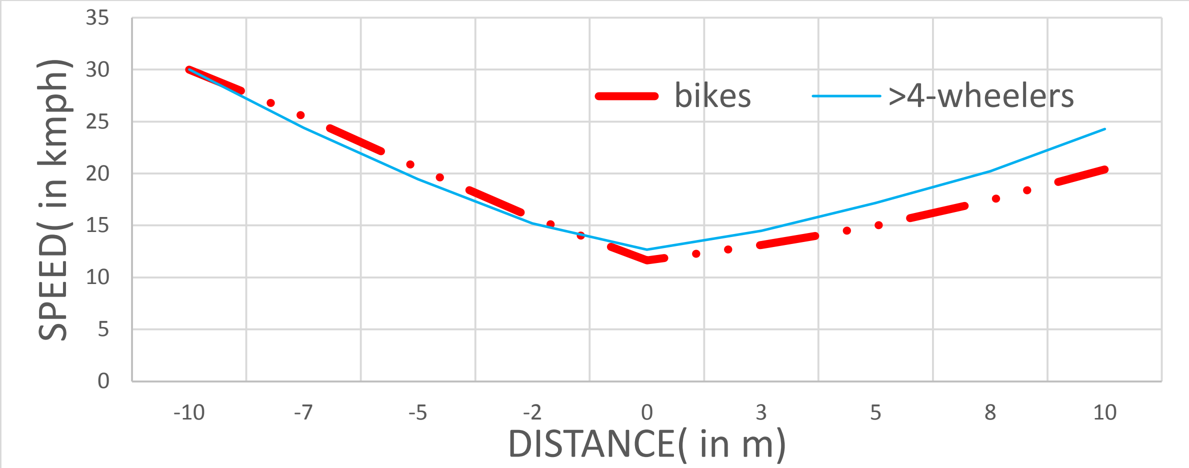

Figure 11. Reduction due to 2 and >4-wheelers

- For vehicles > 4wheelers across bump the speed reduction at bump is 57.74% whereas for bikes its 60.4%.
- For vehicles > 4wheelers across bump the speed reduction at distance 10m is 19.09% whereas for bikes its 33%.

4.4.6. FOR comparison between different cities w.r.t 4-wheelers:

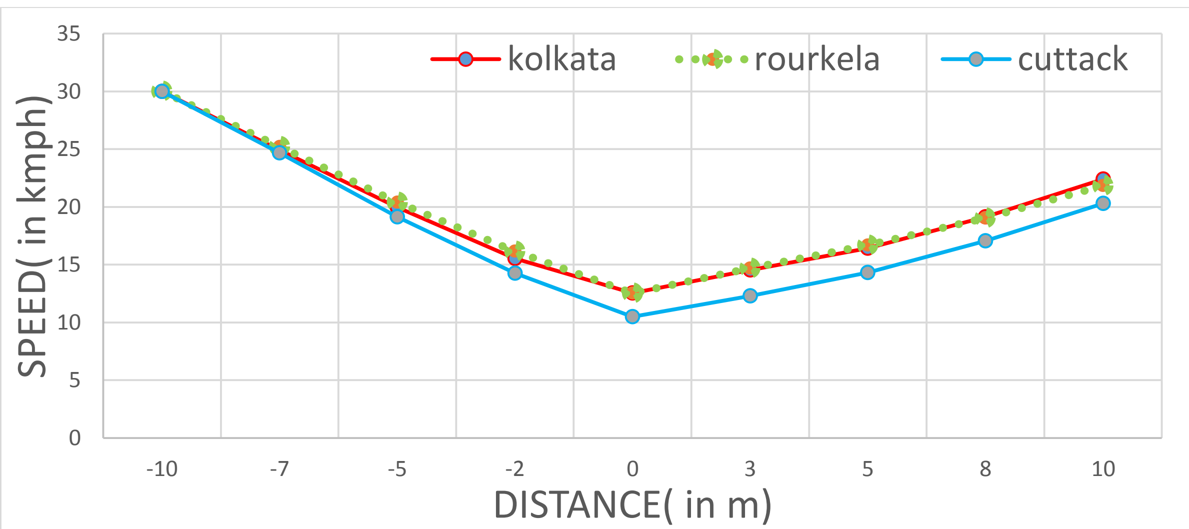

Figure 12. Reduction for different cities

- For Cuttack across bump the speed reduction at bump is 67.33% whereas for Rourkela its 57.45% and for Kolkata its 60.83%.
- For Cuttack across bump the speed reduction at distance 10m is 35.56% whereas for Rourkela its 25.15% and for Kolkata its 30.82%.

4.5. SPEED OVER BUMP:-

There is a wide range of speeds when vehicles pass over the road bump indicating that there is a variation in the response of drivers to the existence of the bump. The response could range from full compliance to the purpose of having the bump (i.e. to slow down traffic) to that of utter disregard of the bump (even though by not slowing down enough may cause a certain level of discomfort to vehicle occupants). The average speed over bump for cars and motorcycles are illustrated in terms of cumulative frequencies as shown in fig 13.

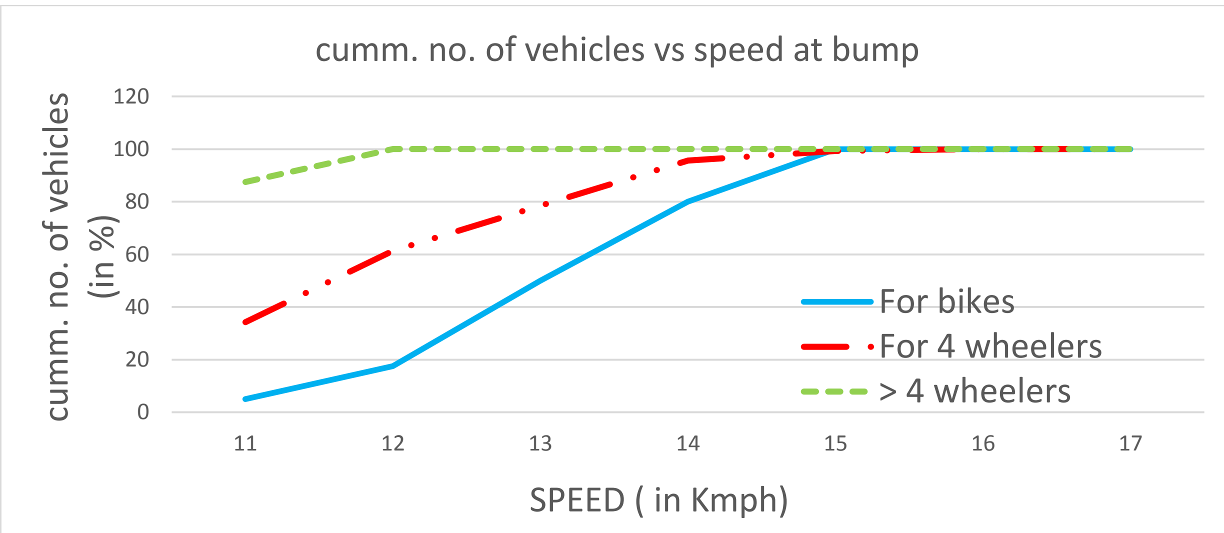

Figure 13. Vehicles speed distribution over bump

In general, it is found that the average speed over bump differs between types of vehicles. As illustrated in Figure 2, higher percentage of vehicles>4-wheelers is traveling over bumps beyond a certain speed as compared to 4-wheelers and 2-wheelers. For example, about 99% of vehicles >4-wheelers pass over bump at speeds of 12 Kmph or below while only about 60% of 4-wheelers whereas only 20% of 2-wheeler are in the same category.

4.6. SPEED ON APPROACHING BUMP:-

The cumulative distribution of the vehicle speed at the distance of 10m is shown in fig 14. As illustrated in fig 14, higher percentage of vehicles>4-wheelers is traveling over bumps beyond a certain speed as compared to 4-wheelers and 2-wheelers. For example, about 60% of 4-wheelers at the distance of 10m from bump at speeds of 32 kmph or below while only whereas only 20% of 2-wheeler are in the same category.

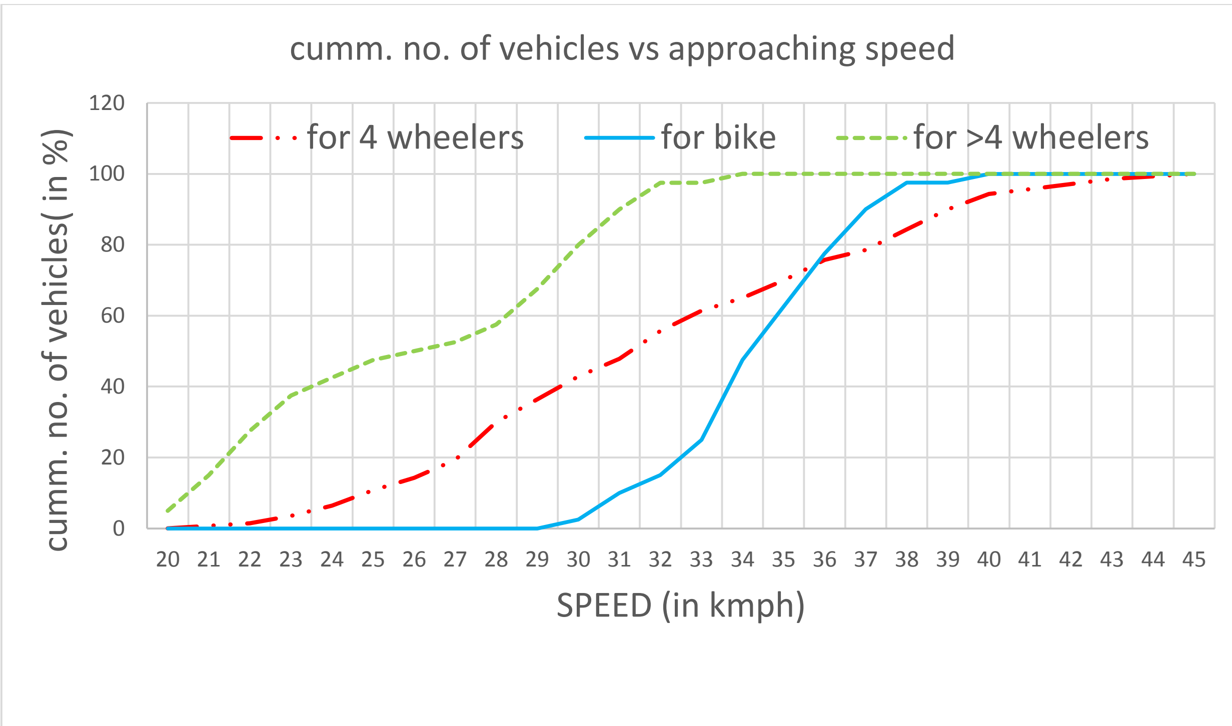

Figure 14. Vehicles speed distribution for approaching

4.7. SPEED OF DEPARTURE FROM BUMP:-

The cumulative distribution of the vehicle speed at the distance of 10m is shown in Fig 15. As illustrated in fig 15, higher percentage of vehicles>4-wheelers is traveling over bumps beyond a certain speed as compared to 4-wheelers and 2-wheelers. For example, about 80% of vehicles >4-wheelers pass over bump at speeds of 22 kmph or below while only about 55% of 4-wheelers whereas only 20% of 2-wheeler are in the same category.

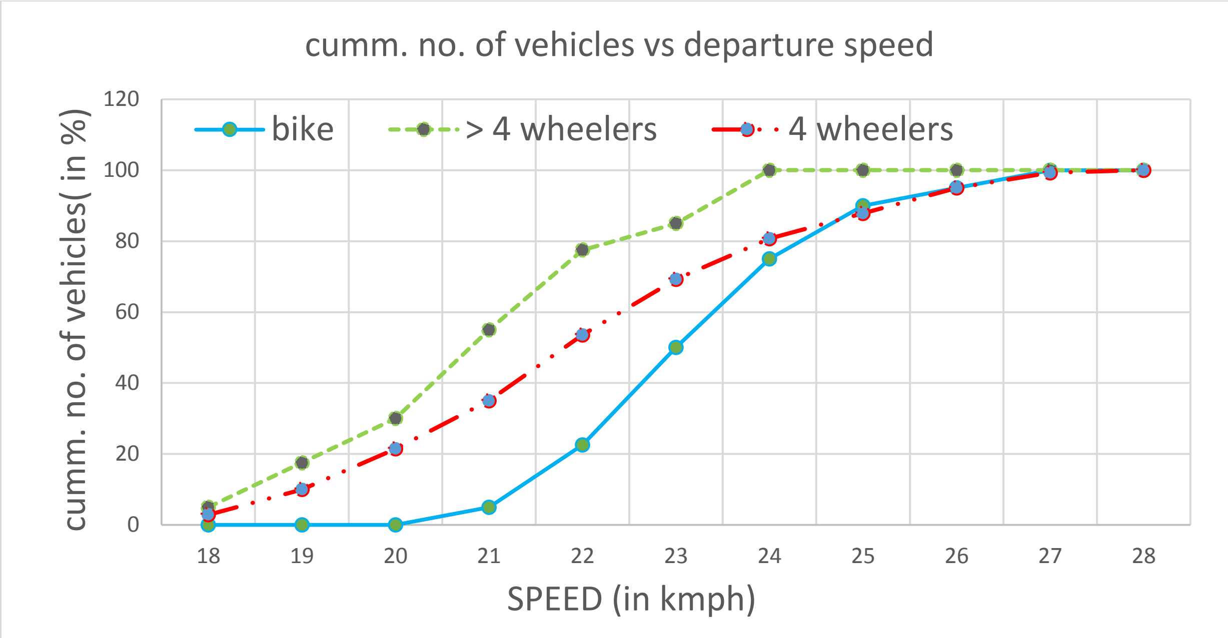

Figure 15. Vehicles speed distribution for departure

4.8. SPEED AT VARIOUS SECTIONS:-

Cumulative distribution of the vehicles against the speed for different sections across the bumps where the marking were done and results were obtained is given in the Fig 16.

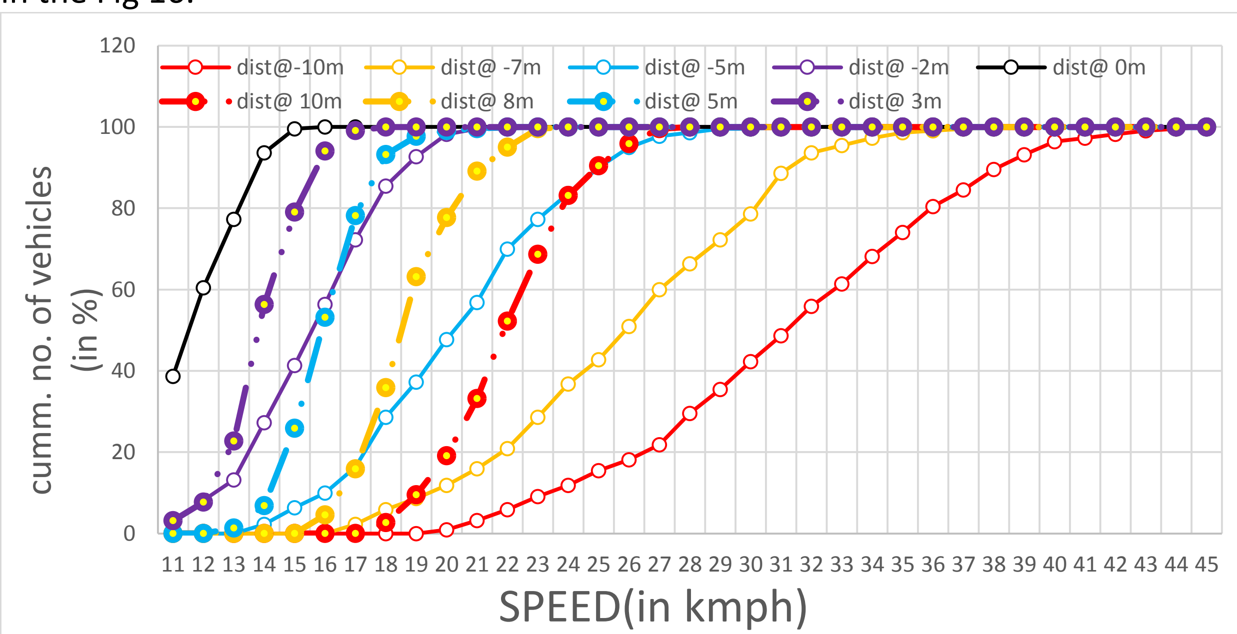

Figure 16. Vehicles speed distribution at various cross section

CHAPTER 5:

STATISTICAL STUDY

5.1. HYPOTHESIS TESTING:-

Hypothesis testing is a procedure, based on sample evidence and probability theory, used to determine whether the hypothesis is an unreasonable statement and should be rejected, or is reasonable and should not be rejected.

HYPOTHESIS: - It is a statement about the value of a population parameter developed for the purpose of testing. For example we can say reduction factor for a bump is 50%.
Hypothesis testing can be done in 2 approach:-

- The probability value (p-value) approach
- The Critical Value Approach

But we can easily do the p-value approach using Microsoft excel.

5.1.1. The probability value (p-value) approach:-

- Develop null and alternative hypothesis.
- Select level of significance (α), 0.10 level for political polling, 0.05 level for consumer research projects, and 0.01 level for quality assurance work.
- Collect data, calculate sample mean and test statistic T-value from the t-test.
- Using this T-value, calculate the corresponding p-value.
- Compare: if p-value < α then reject H_0, else accept it.

As the population standard deviation, is unknown and the data is normally distributed, we use the t-distribution (t-statistic).

5.2. T-TEST:-

A ***t*-test** is any statistical hypothesis test in which the test statistics follows a student's t-distribution if the null hypothesis is supported. It can be used to determine if two sets of data are significantly different from each other, and is most commonly applied when the test statistic would follow a normal distribution if the value of a scaling term in the test statistic were known. In statistical significance testing the p-value is the probability of obtaining a test statistic at least as extreme as the one that was actually observed, assuming that the null hypothesis is true.

The p-value for the t test can be directly obtained from Microsoft excel using T.TEST function. P-value is the measure of strength of the evidence against the null hypothesis. T-value,

$$t = \frac{\bar{x} - \mu}{s / \sqrt{n}}$$

Where $\bar{x}$ = sample mean, u= hypothesis mean,
s= sample standard deviation,
n= no of sample.

5.2.1. For vehicles> 4 wheelers in Cuttack and Kolkata:

Now setting hypothesis as
H_0: reduction in Cuttack = reduction in Kolkata
H_a: reduction in Cuttack > reduction in Kolkata

t-Test: Two-Sample Assuming Equal Variances

	Kolkata	*Cuttack*
Mean	0.507752588	0.62679918
Variance	0.0011699	0.00037688
Observations	20	20
Pooled Variance	0.000773392	
Hypothesized Mean Difference	0	
df	38	
t Stat	-13.53683544	
P(T<=t) one-tail	2.04228E-16	
t Critical one-tail	1.68595446	
P(T<=t) two-tail	4.08456E-16	
t Critical two-tail	2.024394164	

Now as p-value < significance level, we have to reject the null hypothesis.
Hence, reduction in Cuttack is more than that of Kolkata for vehicles > 4wheelers.

5.2.2. For 2 wheelers in Cuttack (100mm height) and Rourkela (75mm height):

Now setting hypothesis as
H_0: reduction in Cuttack = reduction in Rourkela
H_a: reduction in Cuttack > reduction in Rourkela

t-Test: Two-Sample Assuming Equal Variances

	Cuttack	*Rourkela*
Mean	0.620148489	0.604191598
Variance	0.000354627	0.000495877
Observations	20	20
Pooled Variance	0.000425252	
Hypothesized Mean Difference	0	
df	38	
t Stat	2.446950013	
P(T<=t) one-tail	0.009571477	
t Critical one-tail	1.68595446	
P(T<=t) two-tail	0.019142953	
t Critical two-tail	2.024394164	

Now as p-value < significance level, we have to reject the null hypothesis.
Hence, reduction in Cuttack (100mm height) is more than that of Rourkela (75mm height) for 2 wheelers.

5.2.3. For 4 wheelers in Cuttack (100mm height) and Rourkela (75mm height):

Now setting hypothesis as
H_0: reduction in Cuttack = reduction in Rourkela
H_a: reduction in Cuttack > reduction in Rourkela

t-Test: Two-Sample Assuming Equal Variances

	Rourkela	*Cuttack*
Mean	0.570180687	0.672684195
Variance	0.002772439	0.001475148
Observations	60	40
Pooled Variance	0.00225617	
Hypothesized Mean Difference	0	
df	98	
t Stat	-10.57203024	
P(T<=t) one-tail	3.48372E-18	
t Critical one-tail	1.660551217	
P(T<=t) two-tail	6.96744E-18	
t Critical two-tail	1.984467455	

Now as p-value < significance level, we have to reject the null hypothesis.
Hence, reduction in Cuttack (100mm height) is more than that of Rourkela (75mm height) for 4 wheelers.

5.2.4. For 4 wheelers in Kolkata (100mm height) and Rourkela (75mm height):

Now setting hypothesis as
H_0: reduction in Kolkata = reduction in Rourkela
H_a: reduction in Kolkata > reduction in Rourkela

t-Test: Two-Sample Assuming Equal Variances

	Kolkata	*Rourkela*
Mean	0.60596303	0.570180687
Variance	0.001087843	0.002772439
Observations	40	60
Pooled Variance	0.002102039	
Hypothesized Mean Difference	0	
df	98	
t Stat	3.823437957	
P(T<=t) one-tail	0.000115689	
t Critical one-tail	1.660551217	
P(T<=t) two-tail	0.000231378	
t Critical two-tail	1.984467455	

Now as p-value < significance level, we have to reject the null hypothesis.
Hence, reduction in Kolkata (100mm height) is more than that of Rourkela (75mm height) for 4 wheelers.

5.2.5. For 4 wheelers in Cuttack (100mm height) and Kolkata (100mm height):

Now setting hypothesis as
H_0: reduction in Cuttack = reduction in Kolkata
H_a: reduction in Cuttack > reduction in Kolkata

t-Test: Two-Sample Assuming Equal Variances

	Kolkata	*Cuttack*
Mean	0.60596303	0.672684195
Variance	0.001087843	0.001475148
Observations	40	40
Pooled Variance	0.001281496	
Hypothesized Mean Difference	0	
df	78	
t Stat	-8.335277618	
P(T<=t) one-tail	1.05311E-12	
t Critical one-tail	1.664624645	
P(T<=t) two-tail	2.10621E-12	
t Critical two-tail	1.990847069	

Now as p-value < significance level, we have to reject the null hypothesis.
Hence, reduction in Cuttack (100mm height) is more than that of Kolkata (100mm height) for 4 wheelers.

5.2.6. For 4 wheeler across a bump 100mm height and 75mm height:

H_0: reduction in 100mm bump = reduction in 75mm bump
H_a: reduction in 100mm bump > reduction in 75mm bump

t-Test: Two-Sample Assuming Equal Variances

	100 mm ht	*75 mm ht*
Mean	0.639323612	0.570180687
Variance	0.00239229	0.002772439
Observations	80	60
Pooled Variance	0.002554818	
Hypothesized Mean Difference	0	
df	138	
t Stat	8.009850125	
P(T<=t) one-tail	2.1478E-13	
t Critical one-tail	1.655970382	
P(T<=t) two-tail	4.29561E-13	
t Critical two-tail	1.977303542	

Now as p-value < significance level, we have to reject the null hypothesis.
Hence, reduction in 100mm bump height is more than that of 75mm bump height.

5.2.7. CONCLUSION FROM T-TEST:

Hence, on the basis of the t-test conclusion is tabulated in order of the reduction obtained by the bump under different location and bump heights.

Table 5. T-test conclusion for reduction due to types of vehicles

TYPE OF VEHICLES	Cuttack	Kolkata	Rourkela
>4-wheelers	More	Less	----
4-wheelers	More	Medium	Less
2-wheelers	More	----	Less

Table 6. T-test conclusion for reduction due to bump heights

Bump Height	2-wheelers	4-wheelers
75mm	Less	More
100mm	Less	More

5.3. ANALYSIS OF VARIANCE (ANOVA):-

Analysis of variance (**ANOVA**) is a collection of statistical method used to analyze the differences between group means and their associated procedures (such as "variation" among and between groups). ANOVA provides a statistical tests of whether or not the means of several groups are equal, and therefore generalizes the t-test to more than two groups ANOVAs are useful in comparing (testing) three or more means (groups or variables) for statistical significance.

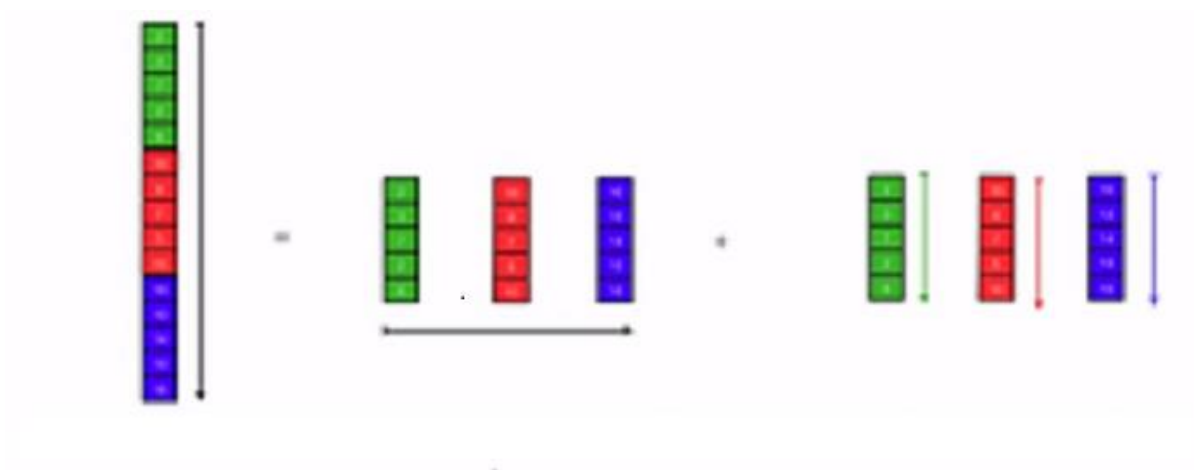

Figure 17. Principle behind ANOVA

Total sum of square = sum of square between groups + sum of square within groups

Total $(\text{variance})^2$ = $(\text{sum of variance between groups})^2$ + $(\text{sum of variance within groups})^2$

⇨ $(\text{sum of variance between groups})^2$= total $(\text{variance})^2$ – $(\text{sum of variance within groups})^2$

$$F = \frac{\text{variance between treatments}}{\text{variance within treatments}}$$

$$F = \frac{MS_{\text{Treatments}}}{MS_{\text{Error}}} = \frac{SS_{\text{Treatments}}/(I-1)}{SS_{\text{Error}}/(n_T - I)}$$

MS is the mean square, I= no of groups, n_T= no of observation.

$$F = \frac{(\text{sum of variance within groups})^2 / (\text{degree of freedom within groups})}{\text{Total }(\text{variance})^2 / (\text{total degree of freedom})}$$

$F)_{Critical}$ is obtained from the table for the corresponding degree of freedoms
If $F)_{calculated} > F)_{critical}$ then the groups are significantly similar.
But if $F)_{calculated} < F)$ critical then are significantly different.

5.3.1. For 4 wheelers in city Cuttack Rourkela and Kolkata:

(Sum of variance within groups)^2= 5.7531+16.3574+4.2426= 26.3531
Total (variance)^2 = 51.6476
⇨ (sum of variance between groups)^2 = 51.6476-26.3531= 25.2946

For within groups degree of freedom= no. of groups -1= 3-1 = 2.
For total degree of freedom= no of observations- no of groups = 140-3= 137.

- ⇨ F = (25.2946*137)/ (51.6476*2) = 33.548.
- ⇨ F critical from table for (a=0.05)= 3
- ⇨ F > F critical
- ⇨ Hence all the observation of the 3 cities are not similar.

5.3.2. For the 3 location of Rourkela:

(Sum of variance within groups)^2= 73.75
Total (variance)^2 = 76.98
⇨ (sum of variance between groups)^2 = 76.98-73.75= 3.23

For within groups degree of freedom= no. of groups -1= 3-1 = 2.
For total degree of freedom= no of observations- no of groups = 60-3= 57.

- ⇨ F = (3.23*57)/ (76.98*2) = 1.1958.
- ⇨ F critical from table for (a=0.05) = 3.094.
- ⇨ F < F critical
- ⇨ Hence all the observation of the 3 cities are similar.

CHAPTER 6:

CONCLUSION

Despite the controversy regarding the use of speed bumps the study has shown that the use of road bumps do actually help in reducing vehicle speed and for the case of the "bump" type hump the speed reduction is quite significant. There is a linear reduction in speed as the vehicle approach the bump and this is quite important in terms of safety because an abrupt reduction in speed due to emergency braking may not be appropriate especially when the weather is wet and this type of weather is common in this country. The application of this type of bumps needs also to be studied with respect to locations which really need them and it should not be applied indiscriminately.

Based on the field experiments on hump height and hump-crossing speeds of two wheelers, 4-wheelers and vehicles >4-wheelers in different location this investigation have shown that statistically the reduction of the speed at hump and at the departure distance of 10m w.r.t to the approaching distance i.e. 10m from left side of bump. It was found that almost over 80% of vehicles speed was reduction by 65% at the bump w.r.t to their approaching speed. Reduction being least for vehicles >4-wheelers and most for the 4-wheelers. It was also seen that more reduction was there as the hump height is increased from 75mm to 100mm.

These relationships provide a useful tool for field engineers to design hump geometry for speed control. This study will enhance the understanding on different types of speed bump and how it can reduce the speed of vehicle while crossing different speed bump design. This understanding can be used in developing geometric design standards that consider an ergonomic approach. This work demonstrates that proper evaluation based on data collection, local knowledge, visual observations and application of engineering principles can help provide a viable traffic calming mechanism.

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