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Analysis of Speed Profiles at Speed Hump under Various Dimensions & Simulating their LOS Using VISSIM

Korra Ravi Kiran[a], Kumar Molugaram[a]*, Manthirikul Sandeep[a]

[a]*Department of Civil Engineering, University College of Engineering, Osmania University, Hyderabad-500007, Telangana, India.*

Abstract

Speed is an important parameter in transportation to attain the design principles. But a fast-moving vehicle can be a forbidding to other road users particularly in heterogeneous traffic. However, at some of the locations speeds are controlled by different traffic calming devices to ensure safety. One of the most adopted traffic calming device in India is speed hump. In this context an attempt is made to study various aspects related to speed hump in Indian context. The present study was done in two phases. The first phase of the study aims to focus on performance of speed hump of different dimensions for different vehicles and establishes a statistical relation between the dimensions of speed hump and vehicular speed using multilinear regression analysis. Calibrated results had shown that there is more than 70% of variation in speed reduction due to change in hump geometry. This study also describes practical geometric design guidelines of speed hump for the use of practicing road engineers. The second phase of the study aims to estimate the performance of vehicles at speed hump by evaluating the delays and level of service of the selected study areas in presence of humps and in absence of humps using micro simulation software VISSIM. Results had shown that due to more number of speed humps Level of Service (LOS) is affected to large extent. These results can be used as a tool for designing hump geometry.

Keywords: Speed Hump; Speed Reuction; Level of Service.

1. Introduction

Traffic calming measures are quite common in modern society. These are physically designed techniques that encourage to force motorists to drive slow and traverse with constant speed which prevent speeding and can increase overall road safety. The main purpose of traffic calming measures is to reduce speed and create a safer traffic

* Corresponding author. Tel.: +91 9849411656
E-mail address: kumartrans@gmail.com

environment. Traffic calming can include the some of the engineering measures, grouped by similarity of method. Narrowing traffic lanes such as curb extensions, pedestrian refuges, small islands, road diets, converting one-way streets into two-way streets can alters vehicle to slow down and traverse along the section without any discomfort induced to drivers in the form of deflections. Raising a portion of a road surface popularly known as vertical deflections techniques such as speed bumps, speed humps, speed cushions and speed tables can create discomfort for drivers while traveling on that portion. Both the height and the steepness of the portion affect the severity of vehicle displacement which forces the driver to slow down. Of all the traffic calming measures mentioned above, speed hump had gained acceptance as a best traffic calming device by several countries including India. A speed hump is a rounded traffic calming device works by transferring an upward force to a vehicle, and its occupants, as it crosses the hump. The force produces a front-to-back pitching acceleration in vehicles having a wheelbase similar to the length of the hump that increases as the vehicles travel faster. 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 hump gently lifts and pitches the vehicle. The acceleration decreases with higher speeds due to absorption of the impact by the vehicle suspension. Various researches have been done on speed hump covering the criteria or the guidelines for the geometrical hump designs, optimization for the designs, effectiveness of the hump, variation of the speed over hump, factors which influence hump designs, etc.

Similarly work done by Philip A. Weber and John P. Braaksma (2005) provides the geometric guidelines for the design of speed hump. The research consists of a two-phase experiment using variations of Watts Profile speed humps and Seminole profile speed humps. In the first phase of the experiment, speeds for vehicles traveling over several of on-road speed humps were recorded to obtain the 85th percentile speeds. Off-road field tests were then carried out using speed humps constructed with wood to the same dimensions as the existing on-road humps. To simulate discomfort, horizontal and vertical accelerations were measured on a test subject as the duplicate humps were traversed at the observed speeds by two automobiles and a regular transit bus. In the second phase of the experiment, further tests were performed using Watts and Seminole Profile humps and two additional designs. The same test vehicles travelled over all the humps. Accelerations were measured using an accelerometer. It was found that the lowest standard deviations among the results from the first phase of the experiment came from examining Root Sum of Square (RSS) accelerations along the horizontal and vertical axes of the test subject. The baseline acceleration level, or discomfort criterion and optimal speed humps for automobiles and transit buses were summarized from the test results. Salau et al., (2004) have focused on vibrational analysis to determine the effect of road humps on a vehicular system. An isolation factor has been calculated which offers guidance to the frequency at which vehicles could travel over road bumps. A mathematical analysis was also done using Fourier series by which they presented the motion of the vehicle in sinusoidal form. Fwa and Tan (1992) has checked the effectiveness of speed hump, zone of influence and speed profiles were drawn. Primary findings of that study included: Speed humps produce the lowest operating speeds and one that is close to the operating speed and spacing of 85 m or less is recommended for speed humps if a speed environment of 40 Kmph is desired. The above studies were limited to field tests and simulation studies of speed hump effectiveness. However, it has been found that not many studies have been conducted to evaluate Level of Service due to speed hump of different combination of geometric design parameters which include length, height and width.

2. Purpose of the Study

Based on the type of vehicle volume and road inventory conditions, two roads were selected for the collection of data in Hyderabad city namely Osmania University Campus main road (3km stretch) and ECIL to NFC main road 2km stretch) as the traffic on the selected sites is heterogeneous type. Speed and volume studies were done with the Radar Speed Gun and video graphic technique respectively to study the variation of speed across speed hump for existing dimensions and to compute the 85th percentile speed of the respective roads. Considering these as inputs to know the behaviour of humps a statistical relationship between dimensions of hump and speed of vehicles was established using multiple linear regression analysis and effect of the 85th percentile speed is evaluated with respect to humps. In order to know the behaviour of vehicle in presence of speed hump and in absence of speed hump, two models were developed for each stretch using micro simulation software VISSIM. vehicle behaviour is evaluated in terms of vehicle delays, formation of queue length and level of service of the total stretch. As the calibrated results were insignificant, appropriate geometric guidelines for speed hump had been suggested.

3. Data Collected

Table 1. Spot Speed Data on Osmania university road

Width(m)	Height (m)	Type of vehicle	Distance at Hump		% speed reduction
			-100	0	
2.82	0.07	Two-Wheeler	42.92	19.39	54.8
		Four-Wheeler	42.28	18.83	56.8
		Auto	36.67	18.31	50
		LCV	33.32	17.45	47.6
		>Four-wheeler	38.52	17.16	55.4
2.945	0.067	Two-Wheeler	43.92	22.23	49.3
		Four-Wheeler	43.16	19.32	55.2
		Auto	33.06	20.61	37.6
		LCV	29.1	20.63	29.1
		>Four-wheeler	33.24	17	48.8
2.945	0.067	Two-Wheeler	39.45	19.99	49.3
		Four-Wheeler	39.52	17.70	55.2
		Auto	33.49	20.88	37.6
		LCV	34.53	19.29	44.1
		>Four-wheeler	37.36	19.12	48.8
2.97	0.1	Two-Wheeler	41.56	20.6	57.8
		Four-Wheeler	40.2	18.9	61.2
		Auto	36.67	17.2	53
		LCV	39.56	18.53	53.1
		>Four-wheeler	40.1	19.2	52.1
3.023	0.11	Two-Wheeler	44.1	18.89	57.1
		Four-Wheeler	43.02	15.94	62.7
		Auto	39.23	17.76	54.7
		LCV	37.53	14.5	61.3
		>Four-wheeler	38.72	13.92	64
2.415	0.115	Two-Wheeler	44.1	17.81	59.6
		Four-Wheeler	42.36	15.32	63.8
		Auto	39.23	17.76	54.7
		LCV	38.65	16.23	58
		>Four-wheeler	38.72	17.56	54.6
2.692	0.097	Two-Wheeler	42.61	19.07	55.2
		Four-Wheeler	41.97	17.09	59.2
		Auto	35.01	19.51	44.2
		LCV	35.68	17.67	50.4

		>Four-wheeler	38.29	17.26	54.9
2.87	0.08	Two-Wheeler	41.01	18.72	54.3
		Four-Wheeler	41.97	17.51	58.2
		Auto	35.01	19.51	44.2
		LCV	33.96	17.77	47.6
		>Four-wheeler	36.52	18.24	50.0

Table 2. Spot Speed Data on ECIL to NFC road

Width(m)	Height(m)	Type of vehicle	Distance at Hump		% speed reduction
			-100	0	
1.93	0.06	Two-Wheeler	41.77	20.35	51.2
		Four-Wheeler	43.26	18.89	56.3
		Auto	38.65	19.28	50.1
		LCV	37.36	18.78	49.7
		>Four-wheeler	36.72	19.04	48.1
2.26	0.06	Two-Wheeler	40.05	19.81	50.5
		Four-Wheeler	39.16	17.86	54.3
		Auto	35.6	19.96	43.9
		LCV	33.16	18.45	44.3
		>Four-wheeler	38.36	19.47	49.2
2.26	0.07	Two-Wheeler	41.93	18.8	55.1
		Four-Wheeler	44.49	18.9	57.5
		Auto	34.84	19.96	42.7
		LCV	34.83	20.03	42.4
		>Four-wheeler	36.84	17.32	52.9
2.23	0.09	Two-Wheeler	42.29	18.26	56.8
		Four-Wheeler	43.16	17.86	58.6
		Auto	37.96	17.82	53.0
		LCV	40.26	18.85	53.1
		>Four-wheeler	40.1	17.95	55.2

Spot speed study was done with the help of radar speed gun in order to find the % speed reduction of vehicles at the speed hump. Speed of all the type of vehicles were calculated at 100 meters before the hump and at the hump and % speed reduction is calculated using below formula.

$$V = \frac{V_{100} - V_0}{V_{100}} X100 \qquad (1)$$

Where,

V is the speed reduction in %,
V_{100} is the speed of vehicles at 100 m distance before the hump in Kmph,
V_0 is the speed of vehicles at the hump in Kmph.

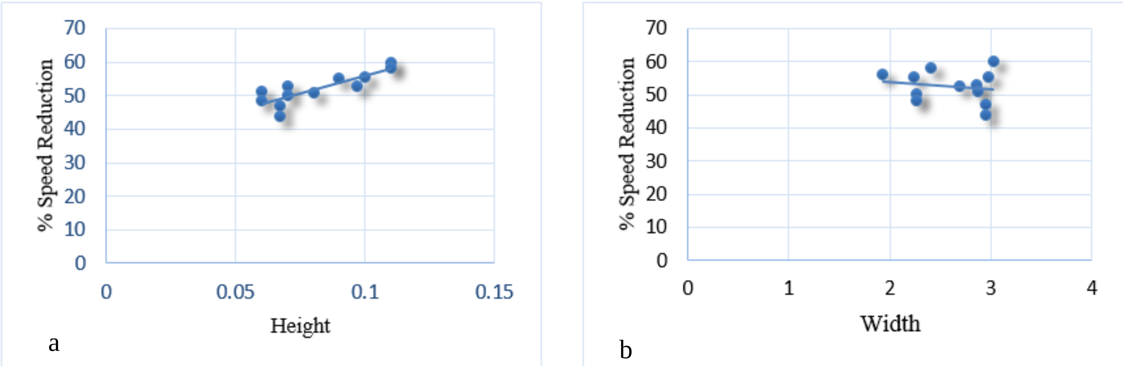

Fig. 1 Relation between (a) Hight; (b)Width of the hump and % speed reduction

Above graphs shows the variation of speed of vehicles with respect to height and width of the hump. As height increses there is a decrease in speeds of vehicles which results in increase of % speed reduction whereas as width increases there is an increase in the speeds of vehicles which in turn decreases the % speed reduction. Therefore the relation between the height of the hump and the % speed reduction is a positive linear relationship and the width of the hump and % speed reduction is negative linear relationship which is statistically shown below.

$$V = 227.5H - 3.4W + 42.5 \tag{2}$$

$R^2 = 0.78$
Significance of F = 0.001041

Where,

H is the height of the hump in meters,
W is the width of the hump in meters.

These statistical results explain that there is a 78% of variability in speed reduction due to change in dimensions of hump and there is only 0.1% of probability that the regression output is random as Significance of F is 0.001041. The intercept of height is in positive which shows the relation is positive linear relationship whereas intercept of width is in negative which shows the relation is negative linear relationship. But there is a large variation of behaviour of different types of vehicles. In this context a statistical relationship is established between dimension of hump and speeds of all the vehicles which are given below.

$$V_{bike} = 171.3H - 2.3W + 46.4 \tag{3}$$

$R^2 = 0.79$
Significance of F = 0.000801308

$$V_{car} = 159.8H - 0.99W + 47.7 \tag{4}$$

$R^2 = 0.92$

Significance of F = 9.41E-06

$$V_{auto} = 261.2H - 6.9W + 44 \tag{5}$$

R2 = 0.58
Significance of F = 0.018104

$$V_{LCV} = 374H - 7.2W + 36.7 \tag{6}$$

$R^2 = 0.65$
Significance of F = 0.008329

$$V_{Greater\ than\ fourwheeler} = 171H + 0.5W + 37.4 \tag{7}$$

$R^2 = 0.53$
Significance of F = 0.031449

Fig. 2 (a) Osmania University Road; (b) ECIL to NFC Road

Except greater than four wheelers, the behaviour of all the type of vehicles is similar i.e., as height increases % speed reduction increases and as width increases % speed reduction decreases. But in case of greater four wheelers, due to its long length of wheel base there is no decrement in % speed reduction even if the width of hump increases because as wheel base increases the distance to be traveled on the hump also increases which in turn related to the width of the hump. Hence speed decreases as width of the hump increases in case of greater four wheelers.

Behaviour of a vehicle at the speed hump not only depends on the dimensions of hump and type of vehicle but also on the road inventory conditions i.e., with respect to the indications of hump. Among the selected study areas, Osmania university road has 13 humps with 3km straight stretch and ECIL to NFC stretch has 14 speed humps with 2 km straight stretch. There is no lane marking, sign boards or any other indication of hump on the ECIL to NFC road as shown in fig 2, whereas on OU road, humps are properly indicated with the markings on the elevated portion of the hump along with the sign boards being placed before 40m from the hump as shown in fig 3. So in order to access the vehicle behaviour speeds were measured for every 20 meters interval before the hump and after the hump on both roads. Following are the speed profiles of different vehicles at hump on OU road and ECIL road. Negative sign indicates the distance before the hump and positive sign indicates the distance after the hump.

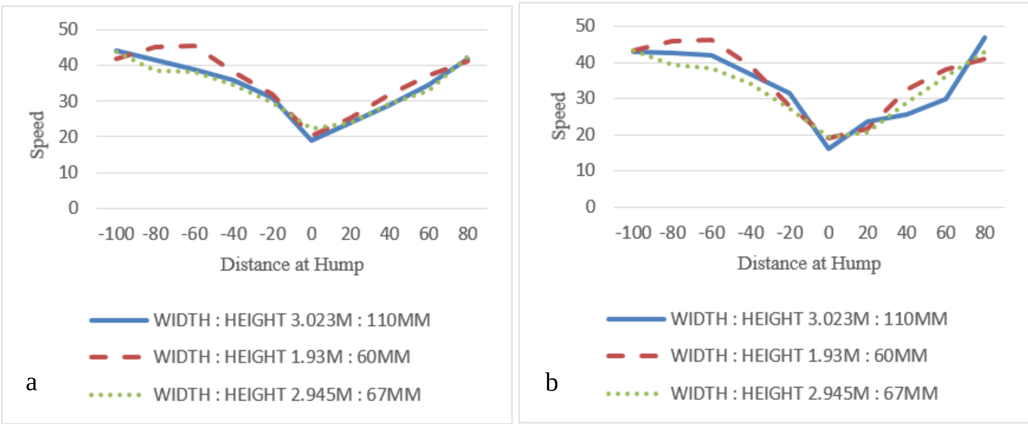

Fig. 2 Speed Profile of (a) Two-Wheeler; (b) Four-Wheeler

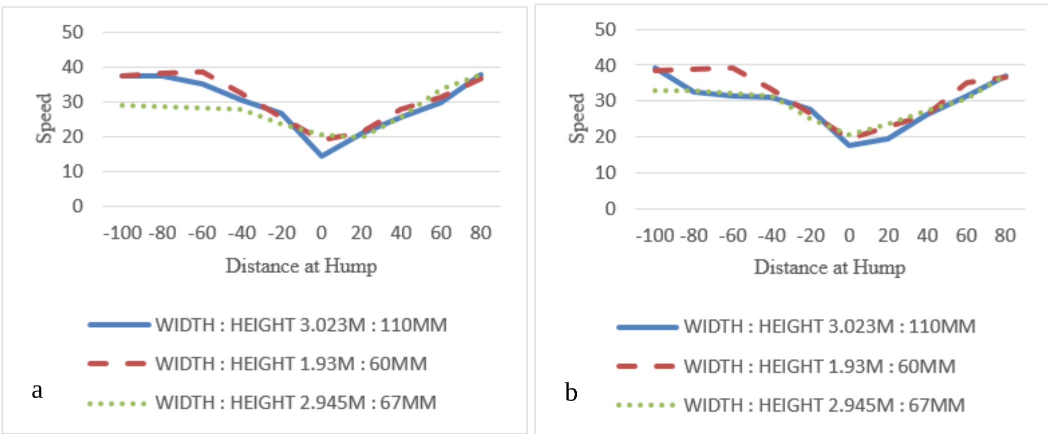

Fig. 3 Speed Profile of (a) LCV; (b) Auto

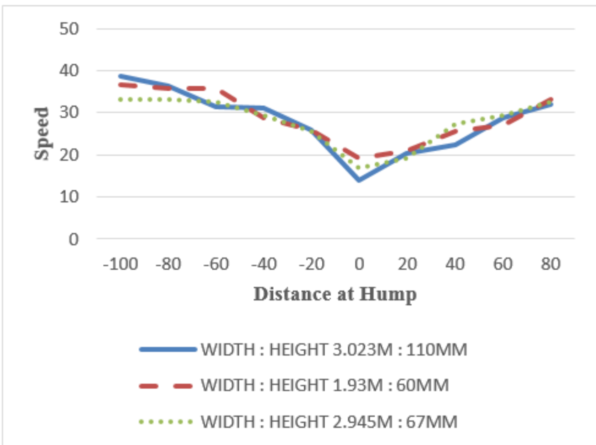

Fig. 4 Speed Profile of Greater than Four-Wheeler

In the above graphs speed hump with dimensions of 3.023m x 110m and 2.945m x 67m are on osmania university road and speed hump with dimensions of 1.93m x 60m is on ECIL road. Due to no proper identification of humps on ECIL road all the vehicles are accelerating even at 100m before hump and are able to identify the hump from the avergae distance of 50m before the hump. Due to sudden decceleration at hump there is a huge deflections on the vehicles and inducing heavy discomfort for the drivers. But in case of OU road, due to presence of markings and sign boards vehicles traversing on the section are able to identify the presence of speed hump from an average distance of 100 meters and are decelerating as per the requirement, which resulting in less deflections on the vehicles and less discomfort for the drivers.

Though there are more speed humps on ECIL road than OU road 85th percentile speed is more effected on the OU road due to clear idication of humps. 85th percentile speed for Osmania university road and ECIL to NFC stretch is same i.e., 42KMPH but on Osmania university road it is reduced by 55% and on ECIL to NFC stretch it is reduced by 50% due to speed humps as shown in the below graphs.

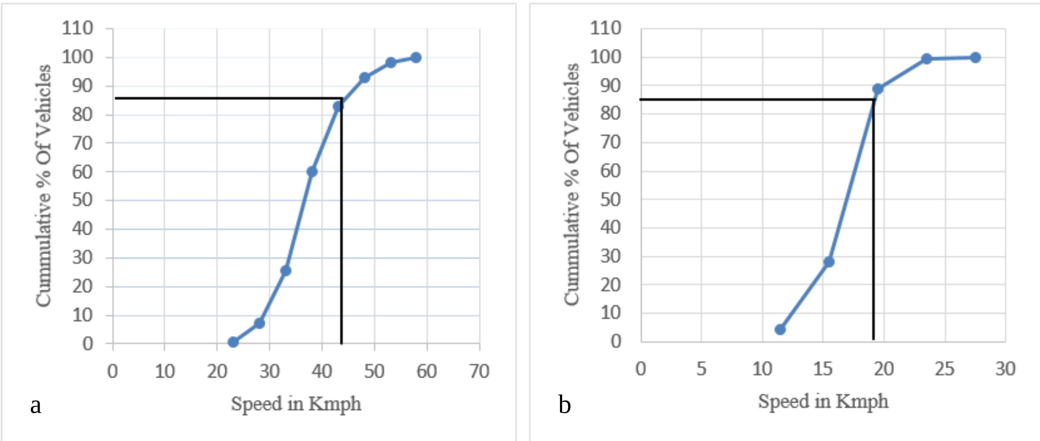

Fig. 5 Osmania University Road Stretch (a) Before 100m of Speed Hump; (b) At Speed Hump

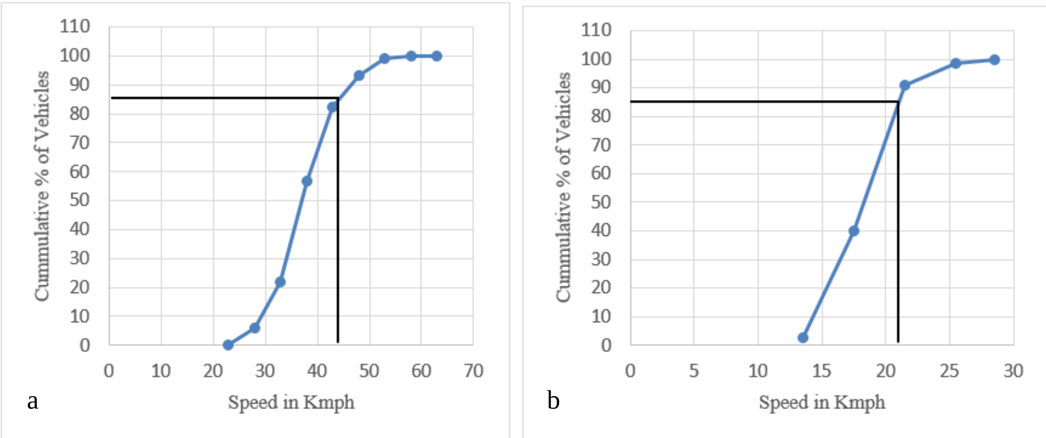

Fig. 6 ECIL to NFC Road Stretch (a) Before 100m of Speed Hump; (b) At Speed Hump

4. VISSIM Model

Using microsimulation software VISSIM two models were developed for each stretch which resembles the existing situation of the selected study stretches. In VISSIM there is no option regarding the speed hump to simulate, but there is an option called Reduced Speed Area (RSA) which is similar to the speed hump. RSA is one of the network object which is used where there is a need to reduce speed. With reduced speed areas, vehicles automatically decelerate before entering the area and enter it at a reduced speed that is inputted. After leaving the reduced speed area, the vehicle automatically accelerates until it reaches its desired speed again. When entering the network, each vehicle is assigned a fractile value for speed distribution. This value remains unchanged during the entire simulation time.

These models were developed to show the real time behaviour of the vehicles in presence of humps and to know the behaviour of the vehicles in the absence of hump. Vehicle behaviour was calibrated in terms of delays and queue length of the particular stretch and performance of the humps were calibrated in terms of level of service of the road.

Two models (with humps & without humps) were developed for each stretch and results were tabulated as shown below. The attributes of the results, LINK NO. indicates the upstream and downstream of the stretch, QLEN indicates the average queue length of the lane in meters, QLENMAX indicates the maximum queue length of the lane in meters, VEHDELAY(ALL) indicates the average delay of the vehicles in seconds and LOS(ALL) indicates the level of service of the stretch.

Table 2. Model of ECIL to NFC Stretch without Humps

Link No.	Qlen	Qlen max	Vehicle Delay (All)	Los (All)
1	0	0	9.13	LOS A
2	0	0	2.73	LOS A
Avg	0	0	6.52	LOS A

Table 3. Model ECIL to NFC Stretch with Humps

Link No.	Qlen	Qlen max	Vehicle Delay (All)	Los (All)
1	27.05	103.21	52.34	LOS F
2	0	0	29.32	LOS D
Avg	13.52	103.21	41.72	LOS E

On ECIL to NFC stretch due to their low volume of vehicles there is no formation of queue length in the absence of humps and the average vehicle delay simulated was 6.5 seconds. Hence the Level of Service of the stretch simulated was A. but there is a variation in LOS of the stretch in presence of humps which is shown in the table 2. The average queue length of the stretch in presence of hump is 13.52 meters and the average delay simulated was 41 seconds which is increased by 34 seconds when compared to the model of without humps. The maximum queue length occurred during simulation time was 103.2 meters. Therefore, there is an effect on the Level of Service of the stretch which is reduced to E.

Table 4. Model of Osmania University Stretch Without Humps

Link No.	Qlen	Qlen max	Vehicle Delay (All)	Los (All)
1	0	0	15.76	LOS C
2	0	0	15.68	LOS C
Avg	0	0	15.72	LOS C

Table 5. Model of Osmania University Stretch with Humps

Link No.	Qlen	Qlen max	Vehicle Delay (All)	Los (All)
1	6.46	76.94	51.30	LOS F
2	0	0	30.05	LOS D
Avg	3.23	76.94	40.32	LOS E

On Osmania university road due to their high volume there is more vehicle delay than ECIL to NFC stretch in the absence of humps which is 15.7 seconds but there is no queue length. Due to these delays the level of service of the road is simulated as C. In case of model with humps, Level of Service is reduced to E due to increased delay and queue length. The average queue length simulated is 3 meters whereas maximum queue length is 76 meters and the average vehicular delay is 40 seconds.

5. Conclusions

From the preliminary test it was found that no speed hump was according to the IRC standards as the dimensions of the hump varies from the hump to hump which is resulting in the reduced effect of hump. In spite of the minimum span between the two-speed humps being 100m to 120m which was recommended by IRC, the span between 3rd & 4th hump on the OU road is 60 meters and the span between 3rd & 4th, 5th & 6th, 8th & 9th, 10th & 11th on ECIL road is 80m, 60m, 30m, 20m respectively. This resulting in the increased queue length and travel time on the stretch. Functioning of hump gets affected if there is no indication regarding the presence of hump. Though there were more speed humps on ECIL road than OU road, 85th percentile speed is less effected on the ECIL road due to lack of identification of hump on that road and vehicles are being affected more due to heavy deflections at the hump because of the sudden deceleration of vehicles at the hump on ECIL road. So, there is a need of lane markings and sign boards on the ECIL to NFC stretch.

From the surveys it was found that the height of the hump & % speed reduction are directly proportional to each other and width of the hump & % speed reduction are inversely proportional to each other. Not only from the survey it was Statistically proven by the regression output that the intercept of the height is in positive and the intercept of the width is in negative. But in case of greater four wheelers the effect of width is same as height does due to its long wheel base. From the models of VISSIM it was concluded that there is a formation of queue length in between the humps of less span, which is affecting the vehicle delay and travel time. These effects were shown impact on the level of service of the stretch. The level of service of the stretch without humps is varies largely when compared to the model of stretch with humps which shows that the existing speed humps are to be revised regarding dimensions, placement and their indication.

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