PERCEPTION BASED LEVEL OF SERVICE FOR SPEED HUMPS IN MIXED TRAFFIC CONDITIONS - A CASE STUDY IN INDIA

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Resume

Speed humps are used to reduce vehicle speeds and enhance the road safety. However, there has been very limited study that discusses the Level of Service (LOS) that a speed hump provides to its road users. The present study attempts to designate LOS for movement on speed humps based on user perception. A perception-based survey in google forms was collected to assess the opinions of daily commuters while moving over speed humps along their regular routes to work which comprised various socio demographic and technical factors along with recommendations and suggestions. The study employed clustering technique to determine the Level of Service range. The results offer valuable insights into the effectiveness and acceptance of speed humps as a traffic calming measure for enhancing the road safety and could serve as a basis for potential improvements in speed hump design and implementation.

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1 Introduction

The speed hump, commonly known as the ”sleeping policeman” plays a crucial role in ensuring road safety and reducing vehicle speeds. Nowadays, traffic calming devices can be found extensively on roads, particularly in densely populated areas. These devices have been proven to be highly effective in controlling vehicle speeds. There are more than 20 types of traffic calming devices, each offering its unique set of advantages and disadvantages [1]. Excessive speed remains a major cause of road fatalities, leading to thousands of deaths and permanent injuries from traffic accidents each year. It has been demonstrated that by reducing the speed, the frequency of accidents decreases significantly. Among various speed reduction measures, speed humps have proven to be the most effective way to reduce speed and lower accident rates [2-6].

The significant decrease in vehicle speeds brought about by traffic calming measures can effectively discourage through traffic and enhance pedestrian safety. However, this reduction in speed may lead to an increase in traffic noise and air pollution levels, creating a controversial situation. Traffic emissions are recognized as a primary contributor to air pollutants such as carbon dioxide (CO_2), nitrogen oxides (NOx), volatile organic compounds (VOC), and particulate matter (PM). In fact, traffic emissions are responsible for up to 80% of the total PM emissions. [7]. Speed humps can occasionally result in noise, cause back injuries, and damage vehicles when drivers attempt to traverse them at excessive speeds [8]. In the context of India, where heterogeneous and mixed traffic is prevalent, the effectiveness of speed humps was briefly discussed by [5]. It was noted that the incorrect placement and improper design of speed humps have been causing challenges in maintaining smooth traffic flow [3].

According to [9], the level of service represents a quality measure that reflects the operational traffic characteristics and how they are perceived by road users. It provides valuable insights into the efficiency and effectiveness of the traffic conditions and the level of satisfaction experienced by the users. The research conducted by [10] devised a level of service measure for fundamental expressway segments through an empirical approach. Their approach involved incorporating customer satisfaction as a critical parameter to determine the level of service. Clustering can be used to classify the level of service criteria for urban streets [11]. Levels of service at median openings were quantified through the application of cluster analysis [12-13]. Authors of [14] applied clustering techniques as an analytical tool to assess the performance of two-lane highways under conditions of heterogeneous traffic. The k-mean algorithm was employed for the clustering analysis and to establish varying levels of service ranges through calibration. However, even after many searches, no results yielded that have calculated the LOS for speed humps.

In this study, K-means clustering was employed to group data points and establish the Level of Service criteria. The cluster analysis was conducted using SPSS software. In this study, the determination of the number of clusters (k) was carried out using the silhouette plot. In developing countries like India, where heterogeneous traffic conditions are prevalent, there is a lack of extensive research conducted on the impact of speed humps on road users, particularly in terms of effectiveness and user satisfaction. Hence, the primary objective of this study was to evaluate the effectiveness of speed humps based on perception-based survey and to develop the appropriate Level of Service range for speed humps on arterial roads under Indian conditions. The study mainly concentrated on assessment of speed humps focusing on road users' perception and their level of satisfaction with these traffic calming measures.

2 LOS and clustering technique

The LOS assesses the performance and effectiveness of speed humps in managing the traffic speed, enhancing road safety, and minimizing vehicle discomfort. The LOS evaluation encompasses multiple factors, including speed reduction achieved by speed humps, vehicle response (e.g., smooth passage or discomfort), user satisfaction, and impact on traffic flow. Achieving an optimal LOS involves striking a balance between speed reduction and minimizing discomfort to vehicle occupants. Proper design and placement play a key role in ensuring passenger comfort. While speed humps enhance safety, they can also impact the traffic flow by requiring vehicles to slow down or come to a complete stop. This can affect overall road capacity and travel times. Different road users, such as drivers, pedestrians, and passengers, may have varying perceptions of speed humps' effectiveness. Their viewpoints contribute to a comprehensive understanding of LOS. The LOS analysis related to speed humps provides a comprehensive view of their impact on road safety and traffic operations. This assessment guides decision-making in designing, implementing, and managing speed hump strategies to create safer and more efficient road environments. The assessment of Level of Service in relation to speed humps has provided valuable insights into their impact on road users and overall traffic conditions. Through a comprehensive analysis of various factors, including user perceptions, preferences, and vehicle-related considerations, this study aimed to determine the effectiveness and implications of speed humps. The findings underscore the multifaceted nature of speed humps' influence on road safety, vehicle comfort, and traffic flow. The evaluation of LOS through factors, such as speed reduction, vehicle response, and user satisfaction has allowed for a holistic understanding of their role in enhancing road safety measures.

Clustering techniques are a fundamental part of data analysis. They aim to group similar data points together based on certain characteristics or attributes. Cluster analysis involves the grouping of objects based on the information present in the dataset that describes their relationships. The primary goal of clustering techniques is to form groups of data where the data points within each group exhibit similarity and differ from data points in other groups. Within a cluster group, the data points are closer to the center of that particular group than to the center of other cluster groups. K-means, k-medoid, and hierarchical agglomerative are among the commonly utilized clustering algorithms suitable for defining the Level of Service criteria.

The K-means clustering is a type of unsupervised hard partitioning method used to address classification problems [13]. The K-means method utilizes the variation within each cluster as a measure to create homogeneous clusters. Its primary goal is to segment the data in a manner that minimizes the variation within each cluster. The process of clustering begins with random assignment of objects to a certain number of clusters. Subsequently, objects are iteratively re-assigned to other clusters to minimize the within-cluster variation, which is calculated as the squared distance from each observation to the center of its associated cluster. If reallocating an object to another cluster reduces the within-cluster variation, the object is re-assigned to that cluster [15]. In the K-means clustering, the number of clusters must be predetermined by the researcher. However, the optimal number of clusters can be determined through hierarchical clustering and then specified in the K-means clustering. Despite this, K-means is generally considered superior to hierarchical methods due to its robustness against outliers and irrelevant clustering variables, which can have a stronger impact on the performance of hierarchical clustering [15]. Additionally, K-means is well-suited for handling large datasets since its computational requirements are lower compared to hierarchical methods [15]. The study's conducted by [16] suggests that the silhouette method is a viable approach for determining the optimal number of clusters (k) in clustering analysis. In various comparative experiments, the silhouette width index demonstrated effective performance [14, 17-18]. The clustering process continues either until a predefined number of iterations are completed, or until the convergence is achieved [15]. Convergence is a crucial aspect of the K-means clustering technique. It signifies that there are no further changes in cluster affiliations, implying stability in the clustering process. Achieving convergence is facilitated through a series of iterations. Lloyd's algorithm is commonly employed in K-means clustering to reach convergence by iteratively updating and refining the cluster centers. It is a widely used heuristic for K-means clustering [19-20]. The Lloyd's algorithm can be described in two straightforward phases. In the first phase, k centroids are chosen randomly, where k represents the number of specified clusters. In the second phase, each data point in the dataset is assigned to the nearest centroid based on the Euclidean distance. If a data point is closer to another cluster's centroid than the initially assigned one, the centroid is updated until all the data points within a cluster are closest to the centroid of that specific cluster. This process ensures that each data point is associated with the most appropriate cluster center, leading to convergence [21].

2.1 Two step clustering technique

The two-step clustering, a data mining technique, involves a process of grouping data into clusters using the two-stage approach. In the first stage, a preliminary clustering is performed to create a set of initial clusters. In the second stage, these initial clusters are merged or refined to create the final clusters. This method is particularly useful for handling large datasets and is aimed at discovering underlying patterns and relationships within the data. The two-step clustering technique exhibits its effectiveness by demonstrating the quality of the clusters it forms. This technique is designed to showcase how well the data points are grouped into clusters, helping to reveal meaningful patterns and relationships within the dataset.

The silhouette measure of cohesion and separation is a metric used to evaluate the quality of clusters formed in a clustering analysis. It combines two aspects: cohesion, which measures how close the data points are within the same cluster, and separation, which gauges how distinct clusters are from each other. The silhouette measure provides a value between -1 and 1, where the higher values indicate well-separated and cohesive clusters, while negative values suggest that data points might have been assigned to the wrong clusters.

2.2 K-Means clustering to classify the clusters

The K-means method utilizes the variation within each cluster as a measure to create homogeneous clusters. Its primary goal is to segment the data in a manner that minimizes the variation within each cluster. The process of clustering begins with random assignment of objects to a certain number of clusters. Subsequently, objects are iteratively re-assigned to other clusters to minimize the within-cluster variation, which is calculated as the squared distance from each observation to the center of its associated cluster. If reallocating an object to another cluster reduces the within-cluster variation, the object is re-assigned to that cluster.

K-Means clustering is employed to check the convergence and to determine the cluster range. K-Means clustering is utilized for the two specific purposes: convergence checking and determining the cluster range.

2.2.1 Convergence checking

In K-Means clustering, convergence refers to the point where the iterative process of reassigning data points to clusters stabilizes. It ensures that the further iterations do not significantly alter the assignment of data points to clusters. By employing the K-Means clustering for convergence checking, the study is likely monitoring the iterative process to ensure that it reaches a stable state, indicating that the algorithm has effectively assigned data points to their appropriate clusters.

2.2.2 Determining the cluster range

The "cluster range" likely refers to the optimal number of clusters for the given data. The K-Means clustering requires the number of clusters to be specified beforehand. Determining the appropriate number of clusters can be challenging, but it significantly influences the quality of clustering results. By utilizing K-Means clustering for determining the cluster range, the study is likely experimenting with different numbers of clusters to find the one that results in the most meaningful and accurate clustering structure for the data.

3 Research methodology

A well-designed research methodology is crucial for generating reliable and valid results, ensuring that the research findings contribute meaningfully to the body of knowledge in a particular field. The current study utilized the study approach presented in Figure 1.

4 Data collection and extraction

In the research process, particularly in studies and projects requiring empirical data, data collection and extraction hold significant importance. Since the present study involves the collection of road user

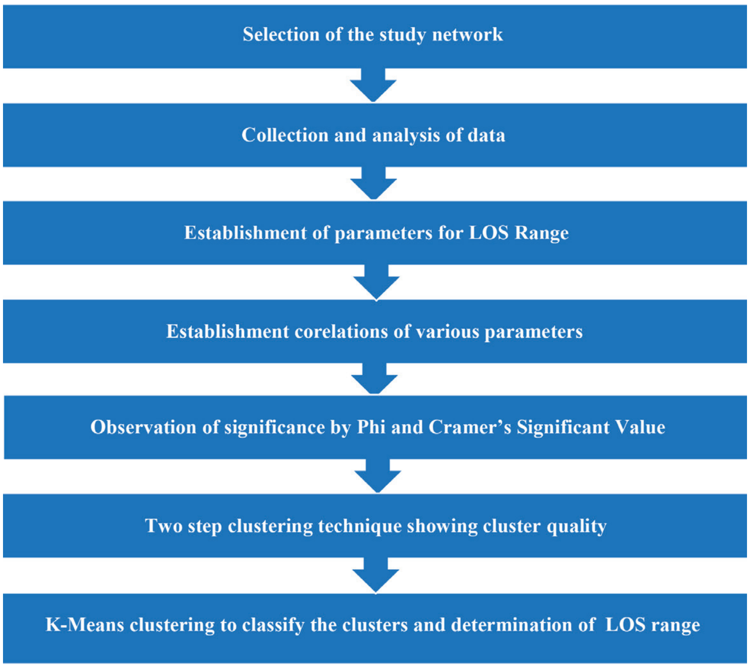

Figure 1 *Flowchart depicting the methodology*

Figure 2 *Snapshots of improperly designed speed hump*

perception while moving on speed humps, therefore their responses in form of questionnaire survey were adopted. The survey was performed among the residents of Bhubaneswar, a smart city in India. The city was selected for the survey since it was noted that most of the speed humps in the city, even on major arterial roads are not adhering to IRC guidelines (IRC 99-2018), despite being a smart city. The average chord length of the speed humps (Mohanty et al., 2021 [3]) in the city was found to be 1.88 meters as opposed to minimum 3 meters as per IRC guidelines. Figure 2 shows one of those speed humps where the chord length is too small. This results in jerky deceleration behaviour leading to negative and unsatisfactory driving experience for the road users.

Therefore, the road user perception survey was carried out among the residents of Bhubaneswar to inquire about their daily commuting patterns to their workplaces, the frequency of encountering speed humps during their daily travels, and their perceptions of these speed humps. The survey encompassed eleven aspects of consideration and requested participants to assign a score to the effectiveness of speed humps. These eleven factors are:

1. Age
2. Gender
3. Category of vehicle
4. Number of speed humps encountering
5. Requirement of speed humps
6. Effectiveness in reducing speeds below 20 km/h
7. Contribution to increase road safety
8. Speed over speed humps
9. Suggestions for speed hump modification
10. Irritation due to excess reduction of speed
11. Vehicle life affected due to too many speed humps

The responses to prepared questionnaire were collected via google forms, direct interview and through hard copies by visiting workplaces. Around 750 number of responses were collected, out of which the partially completed forms were not considered for analysis. A sample questionnaire is provided in the Appendix and a screenshot of the extracted data on excel spreadsheet is presented in Figure 3. The coding (0,1,2,3,4,5…) has been used based on the severity of lowest to highest

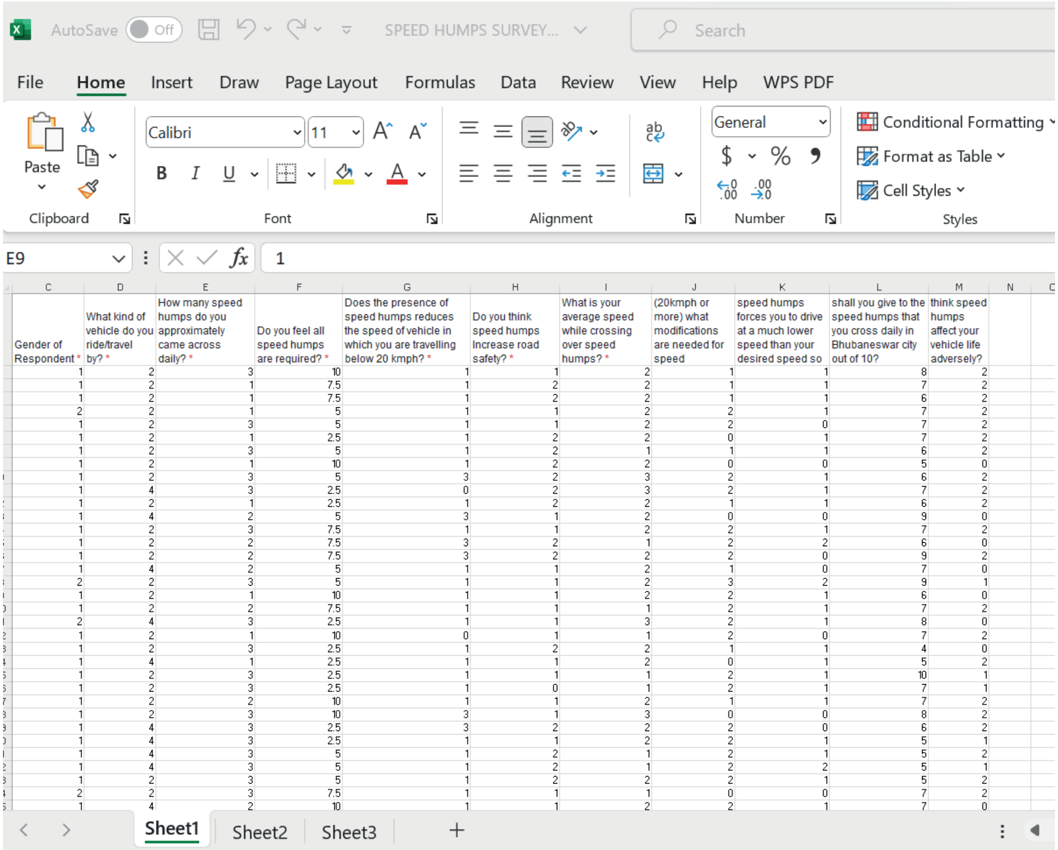

Figure 3 *Screenshot of the extracted data*

for qualitative answers and for various genders and category for quantitative answers. The coding was required for the Statistical Package for the Social Sciences (SPSS) analysis.

The extracted data was entered into the SPSS software for analysis. The research employed Phi and Cramer's statistics to identify the levels of significance for the factors. Factors with significant values below 0.05 were regarded as meaningful, while those with significant values exceeding 0.05 were deemed as not having statistical significance.

5 Results and discussion

The factors utilised for questionnaire survey were correlated with the average scores to understand their importance and impact on the perception of road user for evaluation of speed humps. Phi and Cramer's V are both statistical measures used to measure the strength and significance of associations between categorical variables. These statistics help researchers and analysts to determine whether there is a significant relationship between variables and to what extent they are associated. The results of Phi and Cramer's V are presented in Table 1. It can be observed that 6 factors are found to be significantly affecting the scores provided by road users. These six factors will now be taken into consideration for subsequent analysis.

As can be seen from Table 1, the following factors were found significant to be affecting the perception of road users with regards to travelling on speed humps.

a. Category of a vehicle
b. Number of speed humps encountering
c. Requirement of speed humps
d. Contribution to increase the road safety
e. Suggestions for the speed hump modification
f. Vehicle life affected due to speed humps

According to the provided scores, Table 2 presents the assessment of six distinct factors influencing the road users' perceptions, while traversing over speed humps. These factors have been further categorized into various sub-components, and Table 2 presents the average scores associated with each of them. As exemplified, the "Category of a Vehicle" factor has been segmented into sub-components that reflect distinct vehicle categories. To illustrate, 2-wheelers were assigned an average score of 6.5, whereas cars and jeeps garnered an average score of 6.1, and heavy vehicles obtained a score of 7. The details for each factor and their respective scores are explained in the following paragraph with graphs (Figure 4 to 9) for pictorial representation.

Notes:

Category of a vehicle: This factor is divided into sub components representing different types of vehicles. For instance, the average score given to 2-wheelers is 6.5, while cars and jeeps received an average score of 6.1, and heavy vehicles scored 7.

Table 1 Phi and Cramer's Significant Value of all the factors

Contributing Factors	Phi and Cramer's Significant Value	Remarks
Age	0.518	Not Significant
Gender	0.729	Not Significant
Category of vehicle	0.042	Significant
Number of speed humps encountering	0.000	Significant
Requirement of speed humps	0.000	Significant
Effectiveness in reducing speeds below 20 kmph	0.424	Not Significant
Contribution to increase the road safety	0.000	Significant
Speed over speed humps	0.106	Not Significant
Suggestions for the speed hump modification	0.037	Significant
Irritation due to excess reduction of speed	0.221	Not Significant
Vehicle life affected due to speed humps	0.000	Significant

Table 2 Factors that contribute to the average scores assigned to speed humps

Contributing Factors	Sub components	Average
Category of a vehicle	2 Wheeler	6.5
	Cars and Jeeps	6.1
	Heavy Vehicle	7
Number of speed humps encountering	1 Number	6.7
	2 Number	7
	3 Number	6.1
Requirement of Speed Humps	No Speed Humps Required	3.3
	< 40%	5.6
	40-50%	6.4
	> 50%	6.9
	All Speed Humps Required	7.3
Contribution to increase the road safety	Yes	7.3
	No	3.8
	Not Always	6.0
Suggestions for the speed hump modification	Increase Width of Speed Humps	6.4
	Reduce Height of Speed Humps	6.2
	No Change in Design Required	7.1
	Any Other Suggestions	7.1
Vehicle life affected due to speed humps	Yes (To a higher extent)	5.7
	Yes (But manageable)	6.5
	No	7.2
	Can't Say	7.8

Number of speed humps encountering: This factor is divided by the number of speed humps encountered. The average scores for encountering 1, 2, and 3 speed humps are 6.7, 7, and 6.1, respectively.

Requirement of Speed Humps: This factor considers the respondents' perception of speed hump necessity. Different levels, ranging from "No Speed Humps Required" to "All Speed Humps Required," are presented along with their corresponding average scores.

Contribution to increased road safety: This factor explores whether respondents believe speed humps contribute to increase the road safety. The options "Yes," "No," and "Not Always" are included, along with their average scores.

Suggestions for the speed hump modification: This factor indicates the suggestions provided by respondents to modify speed humps. Different modification suggestions are listed, along with their average scores.

Vehicle life affected due to speed humps: This factor examines whether vehicle life is impacted by speed humps. Respondents' answers range from "Yes

(To a higher extent)" to "Can't Say," with corresponding average scores.

Overall, Table 2 along with Figures 4 to 9 offers a comprehensive overview of how different factors and sub components influence the average scores attributed to speed humps in the survey.

The assigned score for speed humps appears to be influenced by the respondents' age. Younger individuals might have given higher scores, while older respondents may have given relatively average scores. Alternatively, it could be interpreted that older age groups might have provided favorable scores, perceiving speed humps as effective measures for enhancing road safety. In contrast, younger respondents might have deemed speed humps less necessary.

When investigating the correlation between the number of encountered speed humps and the perceived requirement for them, an assumption can be made. If an individual faces an excessive number of speed humps daily, it is plausible that they might express a lesser need for these humps. The rationale behind this assumption is that encountering a significant number of speed humps daily could lead to irritation over time. People who traverse numerous speed humps daily are likely more acquainted with them, enabling them to better determine whether any modifications to the speed humps are necessary.

Drawing insights from both the necessity of speed humps and the irritation resulting from excessive speed reduction, it is evident that improperly designed speed humps and their overabundance can lead to frequent speed reduction, causing annoyance to vehicle occupants. Such irritation could lead to individuals assigning lower scores to speed humps and even expressing the opinion that speed humps are unnecessary in certain situations. In the case of individuals who perceive speed humps as significantly enhancing the road safety, they are more likely to provide higher scores. Conversely, those who feel that speed humps occasionally pose issues might assign more moderate scores.

Category of vehicle - Individuals driving heavy vehicles such as trucks have assigned an average score of seven out of ten. This is likely due to their vehicles having wide tires, which allows for a more comfortable experience when driving over speed humps of various heights and widths. Additionally, passengers traveling in buses generally do not encounter discomfort when crossing speed humps. In contrast, those using 2-wheelers, cars, and jeeps have given lower scores. This is potentially because they might have encountered speed humps with substantial height and width that are not well-suited for their vehicles, resulting in uncomfortable situations for them.

Number of speed humps encountering - Individuals encountering two speed humps on a daily basis have provided an average score of seven. This can be attributed to their familiarity with these two specific speed humps, along with the observation that traversing two speed humps does not significantly affect their vehicle or cause discomfort for the driver or rider. In contrast, individuals who face three or more speed humps daily have given lower scores, potentially due to irritation caused by frequent interactions with these obstacles. They may also believe that encountering numerous speed humps impacts their vehicle's longevity. Notably, there are respondents who claim not to encounter

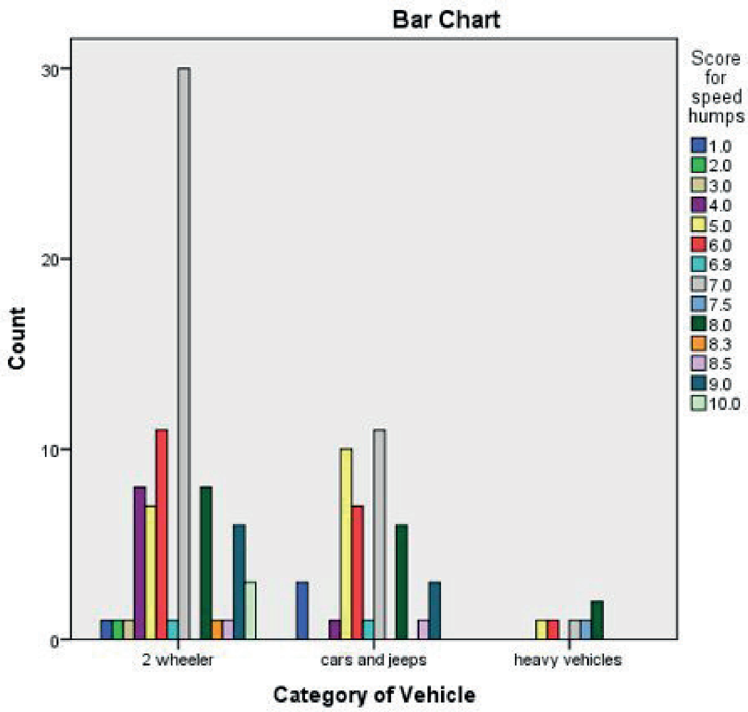

Figure 4 *Scores given by the drivers of various category of vehicles*

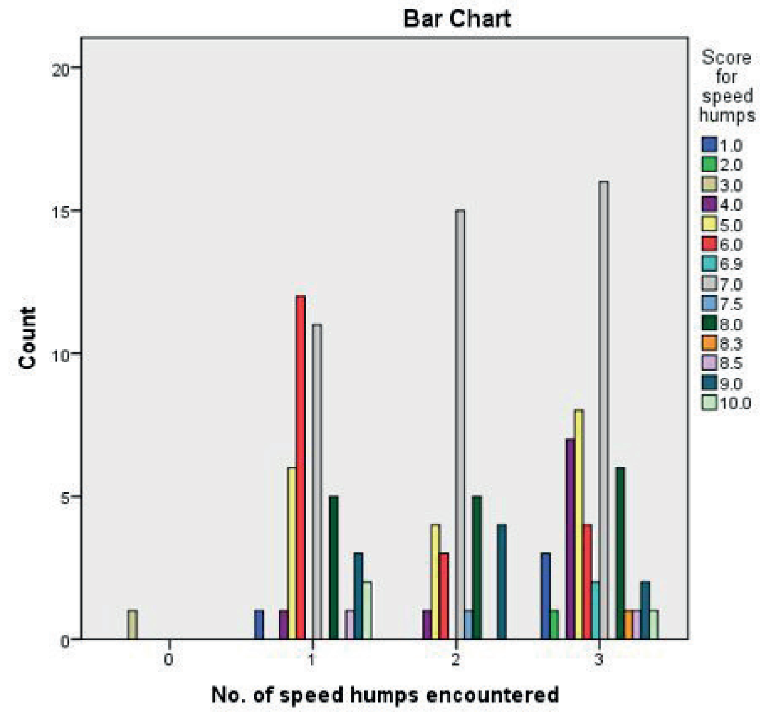

Figure 5 Scores given by the road users encountering the number of speed humps

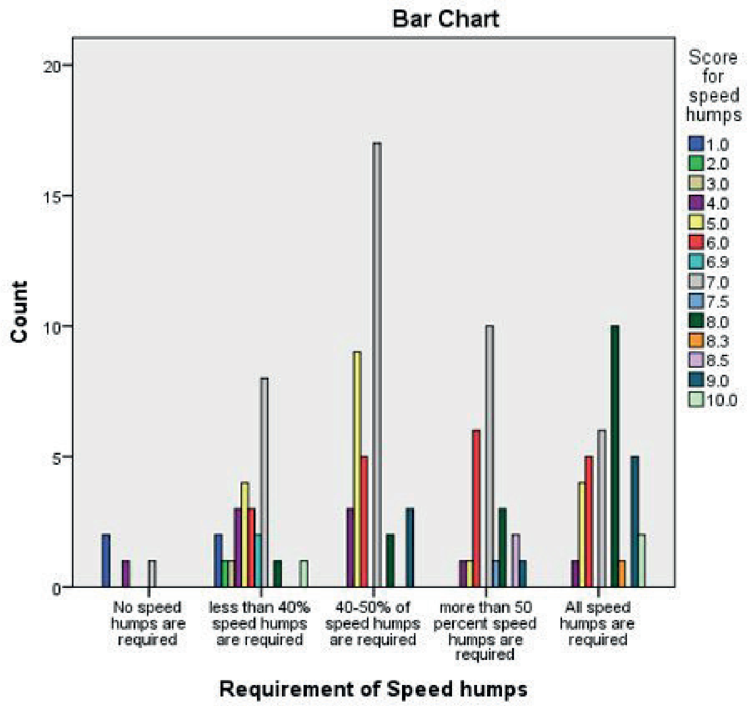

Figure 6 Scores given by the road users on the basis speed of requirements

any speed humps in their daily travels, yet they have still assigned a score. This situation raises questions about the validity of their scoring, thus rendering their viewpoint unreliable. As a result, their scores have been disregarded in the analysis.

Requirement of speed humps - Individuals who perceive the necessity for all s the peed humps to be in place have assigned an average score of 7.3. This group might prioritize road safety over any potential discomfort experienced while crossing speed humps. They likely believe that the speed humps foster driver and rider alertness, leading to an overall increase in road safety. Conversely, those who feel that fewer than 40% of speed humps are required have given an average

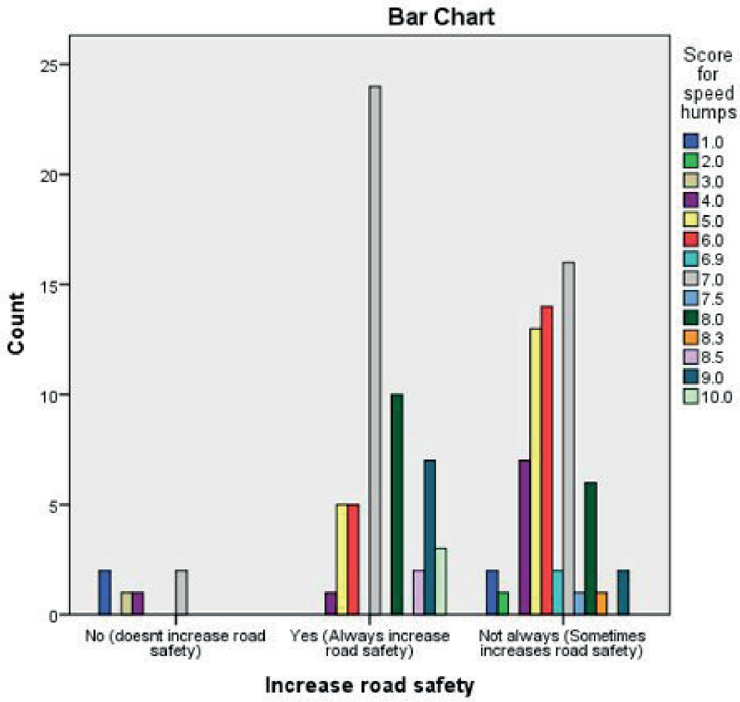

Figure 7 *Scores given by the road users on the basis of road safety*

score of 5.6. This group might find speed humps to be bothersome and detrimental to their vehicle's lifespan. They may also advocate for modifications to speed hump design and a reduction in their numbers. Furthermore, there exists a segment of individuals who deem no speed humps necessary. For these individuals, the primary emphasis might be on speed and comfort rather than the road safety.

Contribution to increase the road safety - A significant proportion of individuals hold the belief that the speed humps indeed enhance the road safety, as evidenced by their average score of 7.3. For them, prioritizing people's safety during road travel takes precedence over other considerations. These respondents likely support the idea of implementing the speed humps universally, viewing them as a means to bolster the road safety. This perspective implies that an increased number of speed humps could contribute to heightened road safety. However, a substantial portion of respondents have assigned scores suggesting that speed humps do not consistently amplify road safety. This group might consider additional factors beyond just speed humps - such as the proper usage of road signs and adhering to speed limits - as crucial contributors to road safety.

Suggestions for speed the hump modifications - Individuals who believe that no modifications are necessary for speed humps have assigned an average score of 7.1. This group perceives speed humps as adequately fulfilling their intended purpose. They find the existing dimensions of the speed humps to be comfortable and devoid of any adverse impacts on both them and their vehicles. Conversely, scores ranging from 6.2 to 6.4 have been given by individuals who advocate for alterations in speed hump dimensions, whether it be in terms of width, height, or both. These respondents have likely encountered issues that prompt them to suggest modifications.

Vehicle life affected due to speed humps - Individuals who hold the view that the speed humps do not impact a vehicle's lifespan have assigned an average score of 7.2. Their assessment might stem from the perception that the dimensions of the speed humps encountered daily are well-suited, posing no problems for their vehicles. Furthermore, these respondents might navigate speed humps at a reduced pace, minimizing external stress on their vehicles and thereby averting any negative effects. Another noteworthy group comprises those who cannot definitively ascertain whether the speed humps affect their vehicle's lifespan. These respondents have provided scores that reflect their uncertainty on the matter.

The two-Step clustering was employed in the study to assess the cluster quality, and the Silhouette value was utilized as shown in Figure 10. The research categorized the scores into six distinct clusters, resulting in an impressive Silhouette value of 0.9, indicating a high level of cluster separation and cohesion. A Silhouette value of 0.9 signifies a remarkably strong level of clustering quality. Such a high value indicates that the data points within each cluster are well-separated from other clusters, and the clustering itself is cohesive and meaningful. Such a value suggests that the clustering results are robust and reliable, portraying

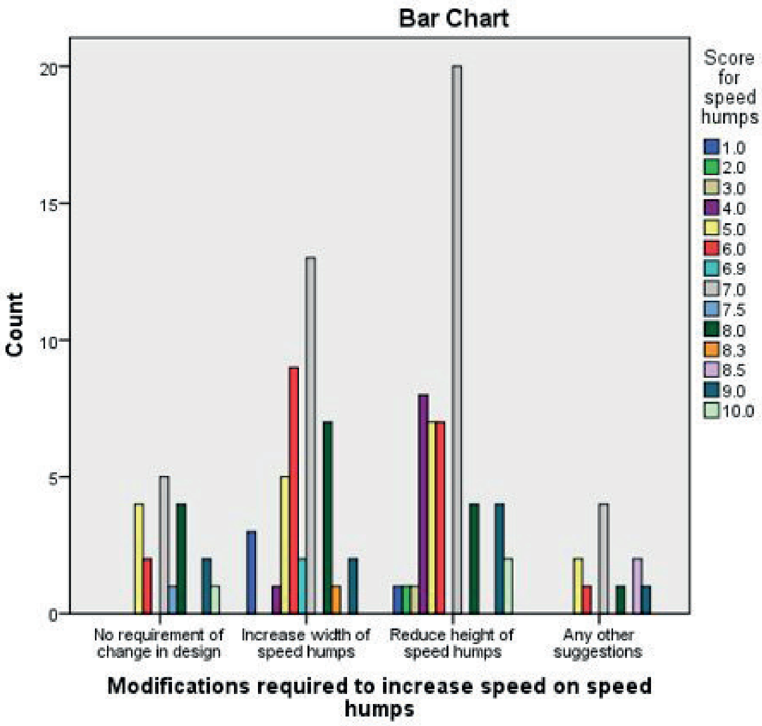

Figure 8 *Scores given by the road users for modification*

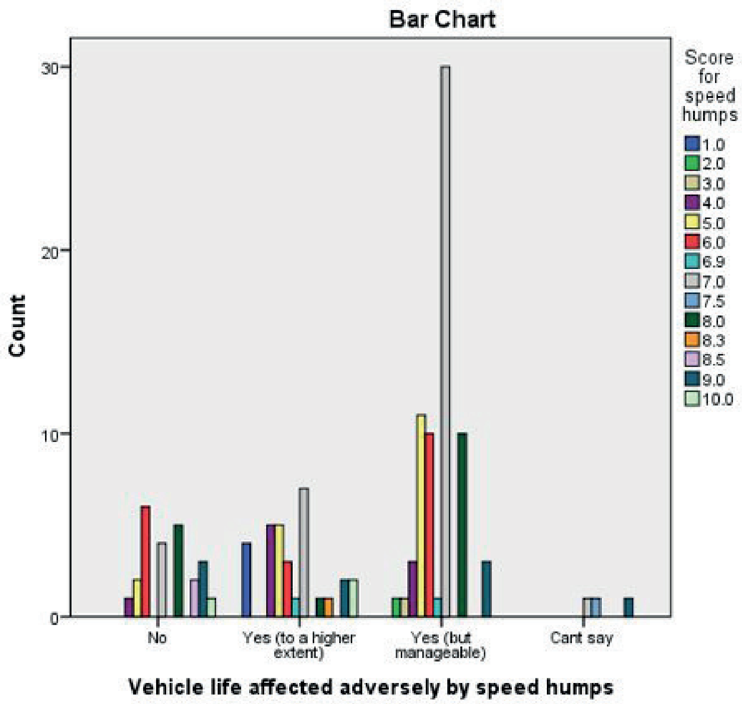

Figure 9 *Scores given by the road users based on vehicle affected*

distinct and accurately separated clusters. Table 3 presents the assignment of those scores to various clusters.

Table 3 categorizes different perceptions of speed humps into clusters based on the assigned scores and is graphically presented by Figure 11. These clusters help identify patterns in how individuals perceive the effectiveness and necessity of speed humps.

Cluster 1: This cluster corresponds to a score of 8.4

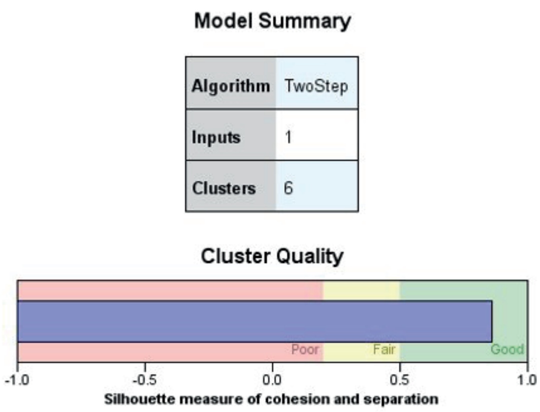

Figure 10 *The two-step clustering technique showing cluster quality*

Table 3 *Assignment of clusters to different scores for the speed humps*

	Cluster					
Score for speed humps	1	2	3	4	5	6
	8.4	6.7	1.2	4.7	10.0	3.0

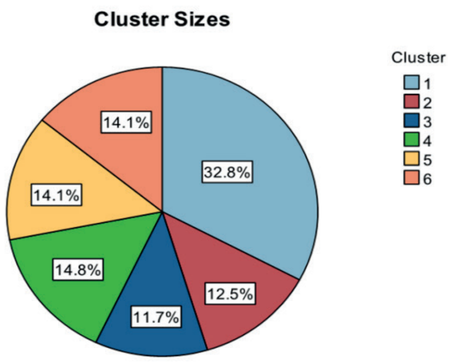

Figure 11 *Details of the clusters*

for speed humps. Individuals in this cluster likely have a positive perception of speed humps and rate them as effective or necessary.

Cluster 2: This cluster is associated with a score of 6.7 for speed humps. People in this cluster might have moderate views about speed humps, indicating that they perceive them as somewhat effective or acceptable.

Cluster 3: This cluster pertains to a score of 1.2 for speed humps. Individuals in this cluster seem to hold a negative perception of speed humps, possibly indicating strong dissatisfaction with their presence o purpose.

Cluster 4: This cluster is linked to a score of 4.7 for speed humps. People in this cluster might have a relatively neutral or balanced view of speed humps, implying that they consider them to have some degree of effectiveness but that there is a room for improvement, as well.

Cluster 5: This cluster is associated with a high score of 10.0 for speed humps. Individuals in this cluster likely have a very positive opinion of speed humps, potentially viewing them as highly effective and essential for road safety.

Cluster 6: This cluster corresponds to a score of 3.0 for speed humps. People in this cluster might have a lower opinion of speed humps, suggesting that they perceive them as less effective or unnecessary.

5.1 Level of service (LOS) range of the speed humps

The LOS (Level of Service) of the speed humps refers to the overall effectiveness and performance of these traffic calming devices. It is a measure of how well the speed humps fulfil their intended purpose of reducing vehicle speeds and enhancing road safety. The LOS is typically evaluated based on several factors, including the design, placement, and impact on traffic flow and user experience.

Different LOS categories indicate varying levels of effectiveness and user satisfaction. A high LOS indicates that the speed humps are well-designed and achieve their intended goals without causing significant inconvenience to road users. Conversely, a low LOS suggests that the speed humps may be ineffective, leading to potential issues such as traffic congestion, discomfort to drivers and passengers, or even damage to vehicles.

To ensure the optimal performance and acceptance of speed humps, it is crucial to carefully consider their design and placement, considering factors such as traffic volume, road type, and user feedback. Regular evaluations of the LOS can help to identify areas for improvement and ensure that speed humps continue to contribute positively to road safety and traffic management.

5.2 Analysis of the cluster and determining the LOS range

Determinations of Range

(Cluster (6) - Cluster (3))/2
= (3.0-1.2)/2
=1.8/2
= 0.9
Now Range = 0 to 1.2 + 0.9 = **(0-2.10)**
(Cluster (4) - Cluster (6))/2
= (4.7-3.0)/2
=1.7/2
= 0.85
Now Rang e= 2.10 to 3.0 + 0.85 = **(2.10-3.85)**
(Cluster (2) - Cluster (4))/2
= (6.7-4.7)/2
= 2/2
= 1
Now Range = 3.85 to 4.7 + 1 = **(3.85-5.70**)
(Cluster (1) - Cluster (2))/2
= (8.4-6.7)/2
= 1.7/2
= 0.85
Now Range = 5.70 to 6.7 + 0.85 = **(5.70-7.55)**
(Cluster (5) - Cluster (1))/2
= (10.0-8.4)/2
= 1.6/2
= 0.8
Now Range = 7.55 to 8.4 + 0.8 = **(7.55-9.2)**
Cluster (6) Range = **(9.2-10)**

5.3 Grouping of the cluster range

The present study attempted to classify the cluster range into six level of grouping like LOS ranging from LOS A to LOS F, table 4.

LOS A means the cluster range is between 9.2 to 10, that means if the score given by road user was in the range of 9.2 to 10, it will be consider as LOS A, which indicates the operational efficiency of the speed humps is in a good condition. Likewise other scores are categorized into different groups. LOS F indicates the operational efficiency of speed humps is the worst condition and it needs an improvement.

From the above grouping it can be said that Group A, a range of which is between (9.2-10) depicts very good LOS. That means people that have given a score lying in the above range find speed humps to be perfect in all the aspects and they do not face any problem while travelling over them. Now Group B, a range of which is between (7.55-9.2) depicts good LOS. That means people who have given a score lying in the above range find that the speed humps are good but they might have faced a little problem while crossing speed humps or their vehicle while travelling over them. Subsequently, the ranges are grouped. For the last group, which is Group F, a range of which is between (0-2.10), depicts a very poor LOS. This means that the people, who have given a score lying in the above range, find the speed humps to be annoying, and as a result affect them and their vehicle adversely, while travelling over the speed hump. They think that a heavy modification is required to the speed humps.

6 Conclusions

Everyday road users do come across at least one or two speed humps while travelling to their destination place. Speed humps take an important role in road safety and traffic management.

The assessment of Level of Service, in relation to speed humps, has provided valuable insights into their impact on the road users and overall traffic conditions. Through a comprehensive analysis of various factors, including user perceptions, preferences, and vehicle-related considerations, this study aimed to determine the effectiveness and implications of speed humps. The

Table 4 *Grouping of the cluster*

Level of service (LOS)	Cluster Range (based on score by the road user)
LOS A	(9.2-10)
LOS B	(7.55-9.2)
LOS C	(5.70-7.55)
LOS D	(3.85-5.70)
LOS E	(2.10-3.85)
LOS F	(0-2.10)

findings underscore the multifaceted nature of speed humps' influence on road safety, vehicle comfort, and traffic flow. The evaluation of LOS through factors such as speed reduction, vehicle response, and user satisfaction, has allowed for a holistic understanding of their role in enhancing the road safety measures. It is evident that the speed humps serve as a significant tool for traffic calming, particularly in areas where the excessive speed poses risks to pedestrians and road users. However, the effectiveness of the speed humps also hinges on their proper design, placement, and maintenance. Striking a balance between the speed reduction and minimizing discomfort to vehicle occupants remains crucial.

This study emphasizes the importance of considering diverse perspectives when assessing the impact of speed humps. Different user groups, such as drivers of various vehicle types, pedestrians, and passengers, have distinct viewpoints that contribute to a comprehensive understanding of the LOS. From the above results and discussions, the study concluded that the speed humps, which are of perfect and standard dimensions, are those in which people do not face any problem while travelling over them. At the same time according to some people's score and response it can also identified that there are also few speed humps that are causing problems to road users. Those speed humps are either affecting them or their vehicle life and are also irritating them. They think that few modifications to the speed humps can make them better and easy to travel. The application of the K-Means clustering, to assess the Level of Service pertaining to speed humps, has provided valuable insights into the perceptions and preferences of the road users. Through the utilization of this clustering technique, we were able to group individuals into distinct clusters based on their responses and scores related to various factors associated with the speed humps. The K-Means clustering analysis unveiled several distinct clusters, each representing a unique perspective on speed humps. Those clusters allowed to categorize respondents based on their perceptions of the speed humps' impact on road safety, vehicle comfort, and overall effectiveness. By examining the cluster assignments and associated scores, we gained a deeper understanding of the diverse viewpoints within the sample. This study's findings demonstrated that the K-Means clustering effectively discerns patterns and nuances in the responses, allowing for a more nuanced understanding of road users' preferences and concerns. This approach not only helps identify varying levels of satisfaction with speed humps but offers insights into the potential improvements that could enhance both the road safety and user experience, as well.

So, the speed humps can be made more carefully and by following strictly to the standard codes so that everyone can travel across speed humps easily. For an effective traffic calming management it is essential to have a carefully planned process which includes clear strategies, goals, and guidelines. In essence, the utilization of the K-Means clustering for analyzing the Level of Service of the speed humps has proven to be a valuable analytical tool. It enables us to comprehensively evaluate the diverse viewpoints of road users, providing a basis for making informed decisions regarding the design, placement, and management of the speed humps. This methodology offers a structured and data-driven approach to enhancing the road safety and traffic management, ultimately contributing to a safer and more efficient road environment for all stakeholders. The evaluation of Level of Service of speed humps sheds the light on the crucial role they play in promoting the road safety and traffic management. This assessment highlights the need for well-planned and well-implemented speed hump strategies that prioritize both safety and user experience. As road infrastructures continue to evolve, a thoughtful approach to incorporating speed humps can contribute significantly to creating safer and more efficient roadways for all. Being the first of its kind, and a unique study for assessing the satisfaction level of the road users while moving on speed humps, the present study could act as a foundation for numerous future studies in this field, including various types of speed humps, different types and configuration of roads, and the acceleration behaviour of vehicles after leaving the speed humps. The future studies can collectively contribute to a specific guideline for the LOS assessment on speed humps in various codes.

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Conflicts of interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix

QUESTIONNAIRE SURVEY FOR PERCEPTION WHILE MOVING ON SPEED HUMPS

This survey is solely for the purpose of research. It won't be used for any other purpose and the identity of the participants will be kept anonymous under all circumstances.

Age of Respondent -
Gender of Respondent -
Origin and destination (from home to workplace/education institute) -

1. What kind of vehicle do you ride/travel by?
   a. 2W
   b. 3W
   c. Personal Car
   d. Public car (Ola, Uber, etc.)
   e. Public transit (Bus)

2. How many speed humps do you approximately came across daily?
   a. No speed humps
   b. 1 to 3
   c. 3 to 5
   d. More than 5

3. Do you feel all speed humps are required?
   a. Yes, all are required.
   b. Yes, but most of them are required (> 50%)
   c. Yes, but not all (40 - 50%)
   d. Yes, but very few are required (< 40%)
   e. None of them are required.

4. Does the presence of speed humps reduces the speed of vehicle in which you are travelling below 20 kmph?
   a. Yes
   b. No
   c. Can't Say
   d. Not always

5. Do you think speed humps Increase road safety?
   a. Yes
   b. No
   c. Yes, but not always (50-50)
   d. Can't say

6. What is your average speed while crossing over speed humps?
   a. 0-10 km/h
   b. 10-20 km/h
   c. > 20 km/h

7. For better speed (20 km/h or more) what modifications are needed for speed humps??
   a. Increase width of speed humps
   b. Decrease height of speed humps
   c. Any other suggestions
   d. No changes are required

8. Do you think speed humps forces you to drive at a much lower speed than your desired speed so much so that you feel irritated on seeing speed humps?
   a. Yes
   b. No
   c. Can't say

9. How much mark shall you give to the speed humps that you cross daily in Bhubaneswar city out of 10?

10. Do you think speed humps affect your vehicle life adversely?
    a. Yes, to a much higher extent
    b. Yes, but its manageable
    c. No
    d. Can't say