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Public Evaluation of Speed Humps Performance and Effectiveness

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Abstract

In Egypt, it is believed that speed humps are the cheapest and best solutions to reduce vehicles speed and thus reduce the number of potential accidents. Due to the lack of specifications in Egypt that govern the installation of speed humps, they were spread randomly and with different dimensions without adequate studies. Consequently, this practice can cause adverse effects on the road users and the surrounding environment. For this purpose, a questionnaire was designed to discuss the different effects of using speed humps in Kafr El-Sheikh city as a typical model in the Egyptian cities. To verify that the questionnaire is appropriate for the intended task, it was evaluated by 30 respondents aged 18 years and over. After the trial process, the required corrections were made to the proposed form of the questionnaire. Then, final questionnaires were distributed and 1000 responses were collected from all road users, whether they were pedestrians, drivers, and owners of vehicles or vehicle repairmen by using face-to-face interviews. The responses were analysed using SPSS program. The results reflected that the installation of speed humps contributed greatly to reduce vehicles speed, the flow of traffic and accidents rate. On the other hand, the results proved that humps also contribute significantly to the environmental pollution, damage to the pavement and vehicles especially when they are poorly designed and located. The majority of respondents attributed the random spread of the speed humps to the weakness of the authorities in law enforcement and the prevention of the installation of new humps without authorization. Finally, with the widespread use of speed humps and with the exception of the positive impact on traffic safety, it also has negative impacts on both the economy and the environment. Finally, the use of speed humps can cause many harmful effects to the neighbourhood, if there no strict control on its installation process. Unless specifications and some standards should be strictly followed, other means of traffic calming measures should be considered.

Keywords: Speed Hump; Questionnaire; Traffic Calming; Accident; Public Evaluation.

1. Introduction

Over-speeding is a major challenge of road safety in many countries and often contributes to more than a third of all fatal accidents [1]. Also it is considered an important factor in the severity of all accidents [2].

Considering this, it is of utmost importance to assess the effectiveness of used road safety measures and to search for innovative and versatile solutions that would help solve the arising road safety problems. In addition, to reduce the number of accidents and future rate of potential accidents on the roads. That's why the concept of traffic calming came into being. The Institute of Traffic Engineers (ITE) defined traffic calming as “the combination of mainly physical measures to reduce the negative effects of motor vehicle use, alter driver behaviour, and improve conditions for non-motorized street users.” [3, 4].

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There are many traffic calming measures such as speed humps, speed bumps, speed tables, roundabouts, transverse rumble strips, optical speed bars, textured pavement, and cat-eye reflectors, are spreading across Egypt [5, 6]. While speed humps are always considered as the best and cheapest solution to reduce over-speeding along roads. Since speed humps are very effective means of calming traffic, therefor the main purpose of its installation is to reduce speed and volume of traffic to acceptable limits in order to enhance roads safety for pedestrians and motorists [6].

In an attempt to face the phenomenon of accidents along the Egyptian roads, the government started to find solutions to organize the traffic speed, especially near highly densely populated areas. It found that the best way to reduce the over-speeding is to install humps at certain locations along the roads. This serves two main objectives, the first is to regulate the traffic process, and the second is to reduce the rate of potential accidents.

The absence of specifications standards that govern the process of installation of speed humps in Egypt, whether to determine its geometric dimensions or locations of installation, led to the random spread of speed humps everywhere. However, speed humps may have a negative impact on the level-of-service, as they increase travel time. They can also cause serious damage to vehicles, inconvenience to passengers, increasing pollution and fuel consumption [6]. In short, despite the importance of speed humps effectiveness on road safety, they may have negative impacts on the surrounding environment, vehicles, and pavement and road users.

On the other hand, there is a lack of studies that assess the performance and the effectiveness of speed humps from the point of view of road users and the public. Therefore, there is an urgent need to investigate the different effects of the speed humps and then determine its effectiveness and negative impacts.

So the main purpose of this paper is to:

- Design a short questionnaire survey instrument to discuss different effects of speed humps such as the impact on vehicle speed, vehicle breakdown, pavement condition, accident rate, places where are installed, surrounding environment, etc.
- Check the designed questionnaire in order to ensure its suitability for generating information about the different effects of speed humps from the point of view of the public.
- Conduct a statistical analysis of the received responses to evaluate the performance and effectiveness of speed humps.

Finally, this paper presents a field study to collect and analyse data for the reason of evaluating the effects of speed humps in public perceptions. A questionnaire was prepared to study the environmental impact, the economic impact, the various activities adjacent to the location of a hump and the reasons for the installation of speed humps. Other factors discussed in the questionnaire, such as the effectiveness of the presence of the speed hump to reduce the number of accidents, the effectiveness of road signs in checking and controlling the traffic, the effectiveness of law enforcement agents, the vehicle speed and rate of traffic flow before and after the erection of speed hump. The questionnaires were distributed in different areas in the city of Kafr El Sheikh, Egypt and the responses were received. Data collected from questionnaires were analyzed using the SPSS program.

2. Literature Review

It is certainly that with the increase of traffic speed, the possibility of fatal injury for road users also increases intensively [7] as shown in Figure 1. High traffic speed on local roadways led to an increase of unsafe roadway conditions for pedestrians and bicyclists. Therefore, many countries in the world seek to increase the level of safety for road users, especially in populated areas [8]. To achieve this goal, some means were used to calm traffic. The main objective of using the traffic calming techniques is to control and reduce the speed of vehicles so as to minimize potential accidents.

The speed humps are being used in Egypt and many countries in the world as a technique to calm the traffic. However, very few studies and researches were carried out in Egypt to evaluate the various effects of using speed humps.

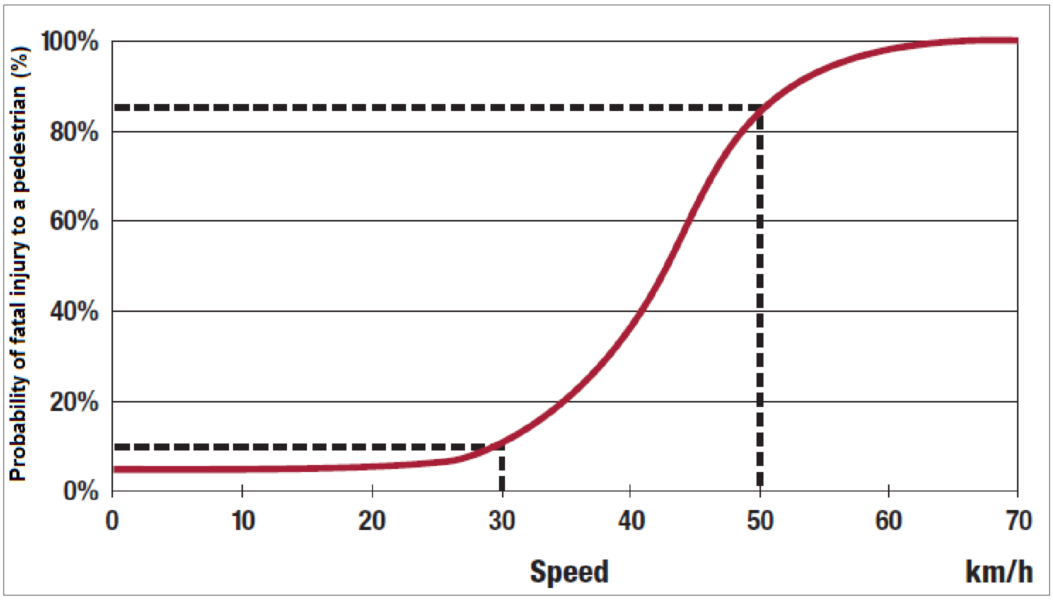

Figure 1. Probability of Fatal Injury to a Pedestrian with Increases in Speed [7]

2.1. Speed Hump

A speed hump is a raised, paved deflection, oriented transversely to the flow of traffic, and having a sinusoidal, circular, parabolic or flat-topped profile in the direction of travel [6]. The purpose of the hump is to force drivers to reduce their speeds to mitigate an ‘‘unpleasant’’ bounce or jolt when traversing the device [6]. They are the most common type of traffic calming devices due to their low cost and easy installation. The most common design of speed humps is the Watts Profile or circular hump. Most vehicles can traverse them safely at 25-30 km/h. Speed humps are designed to create a rocking motion that increased driver discomfort as crossing speed increased [4].

Normally, speed humps are 3.70-4.25 m in length and up to 0.15 m in height. On an exception basis, humps may be shorter or longer than the typical design. The lengths and heights of the humps determine the speed at which traffic will travel over them. Shorter lengths and greater heights force most vehicles to slow down considerably [6].

Not to be confused with a speed hump, a speed bump is a raised area commonly used in parking and on some private roadways, which is generally from 7.50-15.0 cm in height with a length of 0.30-0.90 m in the direction of travel [9].

2.2. Effect of Speed Humps on Speed and other Factors

There are many researchers who have studied the possible positive and negative effects of calming devices, especially speed humps [10-12]. The results of these studies showed that these devices can decrease speed and increase safety on the road. In contrast, they can increase the fuel consumption and noise levels.

In Malaysia, a study was conducted by Radhiah binti Bachok et al. (2017) to determine residents’ perceptions on the effectiveness of speed humps in improving the living environment [13]. A questionnaire was distributed to 478 respondents. They were asked if the speed humps had improved the living environment by reducing vehicles speed and noise. By using the questionnaire data, binary logistic regression models were developed. Descriptive analysis was carried out to evaluate changes in average vehicles speeds and noise levels for the selected speed humps. The results showed that speed humps were effective in reducing vehicle speeds but ineffective to reduce noise levels [13]. Lee et al. (2013) carried out a study to assess the effectiveness of various traffic calming measures from the perspective of performance, traffic safety, environment and public health impacts [14]. Two types of speed humps, speed tables, and chicanes have been used in order to apply the proposed framework so that its usefulness can be verified. The results proved that chicane is better than the other types of traffic calming measures considered, except for vehicle emissions [14].

There are some researchers who have studied the impacts of speed hump geometry on passenger’s comfort and human health. Kordani et al. (2014) carried out a study to investigate the vehicle's dynamic response to different types of speed humps via dynamic simulation modeling [15]. The results showed that ramp's length has the most effect on the dynamic performance of flat-topped humps. Also the sinusoidal profile appears to be an appropriate option from the viewpoint of hump's efficiency [15]. In a related context, Khorshid et al. (2017) carried out a field study to compare different design shapes of speed humps with regard to comfort and human health [16]. The study indicated that the speed hump with cycloidal and Seminole profiles have better performance than the used speed humps on public roads. The results also proved that currently installed speed humps on public roads are not effective against vehicles equipped with active suspension systems or sports cars [16].

According to the study conducted by Engel and Thomsen (1992), the speed of the vehicle decreases by one kilometer per hour for each centimeter increase in the height of the speed hump [17]. There are also a number of studies that have examined the effect of changing the characteristics of the hump/bump on vehicle speed [18-20]. The effect of changing the bump height on speed reduction was studied by Antic et al. (2013) by using heights (3, 5 and 7 cm) with a constant bump length [18]. The speeds were measured one day and a month after the bumps were installed. By using ANOVA analysis and post hoc analysis, a comparison of measured speeds was done. Median speed (V50th) percentile and operating speed (V85th) percentile were used in the comparison before and after speed bumps installation. The results of the analysis confirmed that there is a clear reduction in the speed of vehicles in places where speed bumps were set, compared with the period before installation.

There are also several studies on the impact of humps on pedestrian safety, increasing emissions rates and acceptability of speed humps. In the same context, the study conducted by Mahdy (2012) showed that there was a significant decrease in speed in places where the humps were installed [19]. Clitan (2017) used microsimulation softs to assess the potential problems regarding the speed humps location and proposes some improved solutions, with effects on traffic, pollution, and safety. The study showed that the emissions rates are depending on the geometry of the hump [20].

A study was conducted by Liu et al. (2006) to investigate the preference and acceptability of various traffic calming measures using a visual preference survey [21]. In this study, many road users, including drivers, pedestrians, and cyclists, participated. As a summary, despite the widespread use of speed humps, this measure has received the least assessment of its ability to improve road safety [21]. In Nigeria, Chukwugozi (2014) carried out a study to assess the acceptability of speed humps installation. One hundred questionnaires were randomly distributed among road users. The results showed that the installation of speed humps has a negative impact on road users such as vehicle damage, increasing time spent in reaching the destination, noise and etc. So, many people refused the installation of speed humps [22].

Impact of speed humps on traffic delay was studied by many researchers. For example, Al-Omari and Al-Massaeid (2002) developed a model to assess the impact of speed hump characteristics on delay times in Jordan [23]. The model indicated that speed humps caused significant delays at their locations.

Several researchers inspected the effects of speed humps on traffic volume and noise level and the harmful impacts of the speed humps were confirmed. In Kuala Lumpur, Rosli and Kadar Hamsa (2013) conducted a study to verify the impact of bumps on the level of noise and traffic volume in a residential area. They collected field data on noise level and traffic volume in three residential streets [24]. The measurements on noise level showed the highest traffic volume and the highest noise level in the first street. The correlation analysis pointed to a similar pattern in the relationship between the volume of traffic and the noise level. In the same context, there are a number of studies confirmed the harmful effects of the speed humps on the noise and vibration increasing [25-28].

Very few studies seem to have been conducted to study the effect of speed humps on pavement condition. Bekheet (2014) conducted a study to investigate the potential effects due to using of speed humps on pavement condition in Alexandria, Egypt [29]. The results showed that the presence of such humps could reduce the average pavement condition index (PCI) of the examined road sections by up to 19-points. Abdel-Wahed and Hashim (2017) carried out a study to collect and analyze visual inspection data for the reason of evaluating the impact of speed humps on pavement [6]. They used 52-speed humps located in an intercity two-lane, two-way road that connects two cities, Tahta and Gerga, in Upper Egypt. Using statistical analyses, the correlations between the pavement conditions and hump characteristics were examined. The results proved that the pavement conditions are greatly influenced by the presence of speed humps and hump characteristics.

2.3. Development of Questionnaire Survey Instrument

A questionnaire is a research instrument consisting of a series of questions (or other types of prompts) for the purpose of gathering information from respondents. The questionnaire was invented by the Statistical Society of London in 1838 [30]. It is an effective tool in social science research to obtain information about the participants' social characteristics, current and past behaviour, beliefs and reasons for taking action with respect to the subject under investigation [31].

The use of the questionnaire instrument to investigate the public perception of a range of hazards is becoming increasingly common [31-35]. Typically, the questionnaire consists of a number of questions that the respondent must answer in the form of a group. A distinction is made between open-ended and closed-ended questions. An open-ended question asks the respondent to form his or her own answer, while the closed-ended question, the respondent selects an answer from a certain number of options.

3. Methodology and Study Area

There are many techniques available to researchers to enable them to investigate public perceptions. In this paper, a questionnaire survey instrument was chosen to be used in order to collect information about the effects of using speed humps on road users.

It is known that the best effective way to distribute the questionnaire face-to-face interviews method where ambiguous questions can be clarified, a higher response rate, inquire about ambiguous responses and ensure that the questionnaire is filled in a correct manner and reflects the actual views of the participants.

To verify that the questionnaire is appropriate for the intended task, the questionnaire should be tested with at least 20 participants [37]. So the questionnaire was tested with 30 respondents aged 18 years and over with intermediate or higher qualifications. This stage is called "trial process". After the trial process, the required corrections were made. More than thousand copies of the questionnaires were distributed and 1000 responses were collected from road users, whether they were pedestrians, drivers, owners of vehicles and vehicle repairmen.

3.1. Trial Process

During the trial process, there are some aspects of a questionnaire design that should be taken into consideration. These aspects include question design and format, questionnaire length, questionnaire output, classification questions and aims of the survey [36, 37].

In order to properly design questions, all questions must meet a set of conditions in the trial process. Firstly, all questions should be clearly understood by the participants. Secondly, from trail process, questions can be identified which need to be reworded or omitted from the questionnaire. Thirdly, the sequence of questions should be in a proper and logic sequence.

The appropriate length of the questionnaire is an important aspect that can be determined from the trial process. Accordingly, it can be determined the suitable length for the participants and the duration of the interviews.

The data collected should be in a suitable form to be easily analysed and to get maximum benefit from the received data. On the other hand, the classification of the questions helps evaluate each effect separately, where a set of questions is classified to reflect one variable.

Finally, the questionnaire must fulfill all the objectives of the survey. Therefore, the trial process is very important for developing the appropriate design of the questionnaire form in order to achieve the desired results.

3.2. Structure of the Questionnaire

The data were collected from different locations in the city of Kafr El-Sheikh. The questionnaires were designed to collect information on the effects of speed humps on different road user categories in Kafr El-Sheikh city. The questionnaire is divided into five sections as shown in Appendix (I). The first section discusses the factors considered for the erection of speed humps. The second section discusses the activities adjacent to the speed hump area. The third section discusses the environmental impact of speed humps. The fourth section discusses the economic impact of speed humps. Finally, the last section discusses the occurrence of accidents, maintenance of roads, the speed of motorists and traffic flow rate before and after the erection of speed humps, the effectiveness of road signs in checking and controlling traffic and effectiveness of law enforcement. Other data included age, level of education and road user category.

3.3. Study Area

Kafr El-Sheikh governorate is one of the northern governorates of Egypt Delta, along with the western branch of the Nile in the Nile Delta. Its capital is the city of Kafr El Sheikh. According to the last census from the Central Agency for Public Mobilization and Statistics in 2015, the majority of residents in the governorate live in rural areas, with an urbanization rate of only 23.1%. Out of an estimated 3, 172, 753 people residing in the governorate 2, 441, 246 people live in rural areas as opposed to only 731,507 in urban areas. The study was conducted in urban areas of Kafr El-Sheikh governorate. Figure 2 shows the location of Kafr El-Sheikh City in Egypt.

Figure 2. Location of Kafr El-Sheikh City in Egypt (Google Maps)

4. Data Collection

The questionnaires were distributed in different locations in Kafr El Sheikh City. Accordingly, 1000 responses were received from road users, 300 of which were received from drivers, vehicles owners, and vehicles repairmen. Responses were collected during the period from November 2017 to February 2018 where the questionnaire contains 22 closed-ended questions and only an open-ended question.

5. Results and Analysis

The responses were analysed using SPSS (Statistical Package for the Social Sciences) program. The first section of the questionnaire discusses the main aim for the installation of speed hump as shown in Table 1. Where 85.8 % of respondents agreed that the main objective of the installation of the speed humps was to reduce excess speed. This confirms that the majority of respondents believe that speed humps are the cheapest device to reduce the speed of vehicles and thus reduce the number of accidents. However, 35% of participants believe that humps may cause accidents due to wrong overtaking. A number of respondents believe that the wrong overtaking occurs when the hump is poorly designed and poorly located, which makes the presence of the hump as a double-edged sword.

Table 1. The Main Aim for the Installation of Speed Hump

Question code	Choices	Frequency	Percent (%)
Q1	Yes	858	85.8
	No	142	14.2
Q2	Yes	394	39.4
	No	651	65.1

Where [Q1-Q2] are indicated in the questionnaire given in Appendix (I)

The second section of the questionnaire presents the places where bumps can be erected. While in many Egyptian roads, there is a random installation of the speed humps. However, it could be noticed that the most humps are found at educational places, commercial places, hospitals, before non-signalized intersections and before horizontal curves.

Totally, the respondents agreed that speed humps may be erected with 92.1 % at educational places, 57.4 % for commercial places, 81.4 percent for hospitals, 70.7 percent for intersections, 49.6 percent for curves as shown in Table 2. Based on this, it can be said that people prefer to install speed humps at educational places, hospitals, and non-signalized intersections. Also, there is a convergence of rejection and acceptance ratios with respect to the installation of speed humps at commercial places and horizontal curves. This can help the competent authorities to arrange the priorities in the case of installation of new humps.

Table 2. The Places Where the Humps Can Be Installed

Question code	Choices	Frequency	Percent (%)
Q3	Yes	921	92.1
	No	79	7.9
Q4	Yes	574	57.4
	No	42.6	42.6
Q5	Yes	814	81.4
	No	186	18.6
Q6	Yes	707	70.7
	No	293	29.3
Q7	Yes	496	49.6
	No	504	50.4

Where [Q3-Q7] are indicated in the questionnaire given in Appendix (I)

To assess the environmental impact of the use of the speed humps, the environmental problems associated with them were addressed in the third section of the questionnaire. The points discussed in this section are noise, increase the emission rate of exhaust, destruction of the surrounding area, and fill the rain gutters with waste.

In the compilation of the result, the respondents accepted that all environmental problems mentioned above were abundantly present. The problem with the least percentage of respondents was destruction of the surrounding area (51.1%) and that with the highest percentage of respondents was making extra noise (73.6%) as shown in Table 3.

The results reflect that the installation of speed humps contributed considerably to the environmental pollution, which is dangerous to human health. Speed humps are also considered as source of inconvenience because it causes noise.

Table 3. The Environmental Impacts of the Speed Humps

Question code	Choices	Frequency	Percent (%)
Q8	Yes	736	73.6
	No	264	26.4
Q9	Yes	686	68.6
	No	314	31.4
Q10	Yes	511	51.1
	No	489	48.9
Q11	Yes	603	60.3
	No	397	39.7

Where [Q8-Q11] are indicated in the questionnaire given in Appendix (I)

To assess the economic impacts of the speed humps, it was necessary to know their effect on both the pavement condition at hump location and the vehicle. Therefore, in this section of the questionnaire, the impact of speed humps on vehicle breakdown and pavement condition was addressed. As well as the annual cost of repairing potential vehicle breakdowns caused by humps.

It is worth mentioning that the cost of repairing potential breakdowns due to humps has been discussed with only the drivers, vehicle owners and vehicles repairmen, because they are the specialists in this regard.

This evaluation uses a five-point scale or Likert Scale as shown in Table 4. Where Likert-scale uses fixed choice response formats and is designed to measure attitudes or opinions [38]. Respondents may be offered a choice of five to seven or even nine pre-coded responses with the neutral point being neither agree nor disagree.

Table 4. Variable Values According to A Five-Point Scale or Likert Scale

Value		Label
From Q12 to Q22	1.00	Very Low
	2.00	Low
	3.00	Medium
	4.00	High
	5.00	Very High

To assess the impact of speed humps on vehicle breakdowns and pavement damage, the responses were grouped in Table 5. Where the weighted average of responses was 3.10 with respect to vehicle breakdowns as in Figure 3. and 3.55 with respect to pavement damage before and after hump location as in Figure 4. It should be noted that the highest frequency ratio with regard to breakdowns of vehicles was 48.5% "medium effect". But, with regard to pavement damage, the highest frequency ratio was 41.8% "very high".

Table 5. The Economic impacts of the Speed Humps

Variable	Q12		Q13	
	Frequency	Percent	Frequency	Percent
Very Low	41	4.1	25	2.5
Low	188	18.8	82	8.2
Medium	485	48.5	342	34.2
High	201	20.1	418	41.8
Very High	85	8.5	133	13.3
Total	1000	100.0	1000	100.0

Where [Q12-Q13] are indicated in the questionnaire given in Appendix (I)

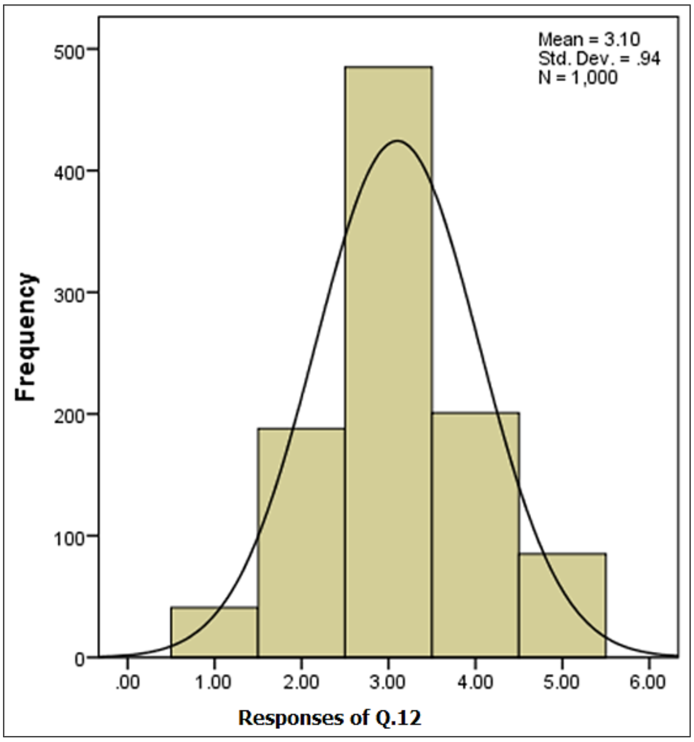

Figure 3. Responses about breakdowns of vehicles versus frequency

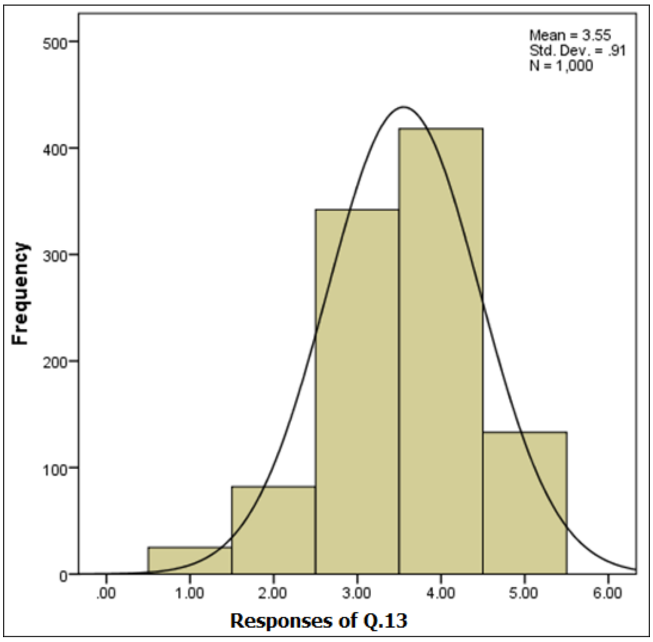

Figure 4. Responses about paving damage versus frequency

To determine the expected annual cost of the vehicles due to the impact of speed humps, a survey was conducted to collect 300 responses from the vehicle owners, drivers and vehicle repairmen. The output of the data analysis is presented in Table 6 and Figure 5. The expected average value of the annual repair cost of the vehicle according to the responses was found 200 US dollars on average as given in Table 6.

Table 6. The Results of Analysis of Responses to Evaluate the Cost of Potential Vehicle Breakdowns

	No.	Range	Minimum	Maximum	Mean	Std. Deviation
Q14	300	524.50	20.00	544.5	200.570	53.424976
Valid No.	300					

Where [Q14] is indicated in the questionnaire given in Appendix (I)

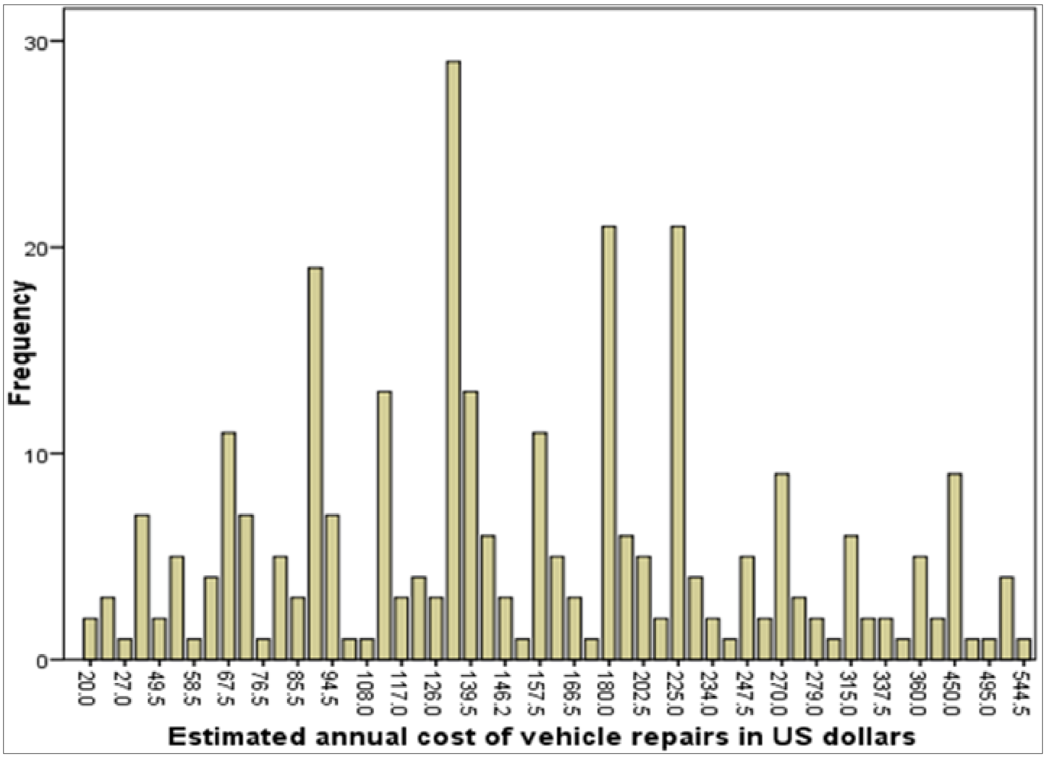

Figure 5. Responses about Estimated Annual Cost of Vehicle Repairs versus Frequency

To assess the effectiveness of the speed hump to reduce the number of accidents and other factors, the responses were grouped in Table 7. Where the weighted average of responses was 3.65 with respect to the effectiveness of the speed hump to reduce the number of accidents as in Figure 6 and the highest frequency ratio was 41.9% "high effect".

While the weighted average of responses was 3.47 with respect to the effectiveness of the warning signs in controlling traffic flow as in Figure 7 and the highest frequency ratio was 34.7% "medium effect".

Table 7. Other Impacts and General Questions

Question number		Very Low	Low	Medium	High	Very High	Total
Q(15)	Frequency	21	77	307	419	176	1000
	Percent (%)	2.1	7.7	30.7	41.9	17.6	100.0
Q(16)	Frequency	27	132	347	335	159	1000
	Percent (%)	2.7	13.2	34.7	33.5	15.9	100.0
Q(17)	Frequency	294	367	250	59	30	1000
	Percent (%)	29.4	36.7	25.0	5.9	3.0	100.0
Q(18)	Frequency	24	23	263	538	152	1000
	Percent (%)	2.4	2.3	26.3	53.8	15.2	100.0
Q(19)	Frequency	46	287	525	105	37	1000
	Percent (%)	4.6	28.7	52.5	10.5	3.7	100.0
Q(20)	Frequency	5	14	107	494	380	1000
	Percent (%)	.5	1.4	10.7	49.4	38.0	100.0
Q(21)	Frequency	67	284	502	126	21	1000
	Percent (%)	6.7	28.4	50.2	12.6	2.1	100.0

Where [Q15-Q21] are indicated in the questionnaire given in Appendix (I)

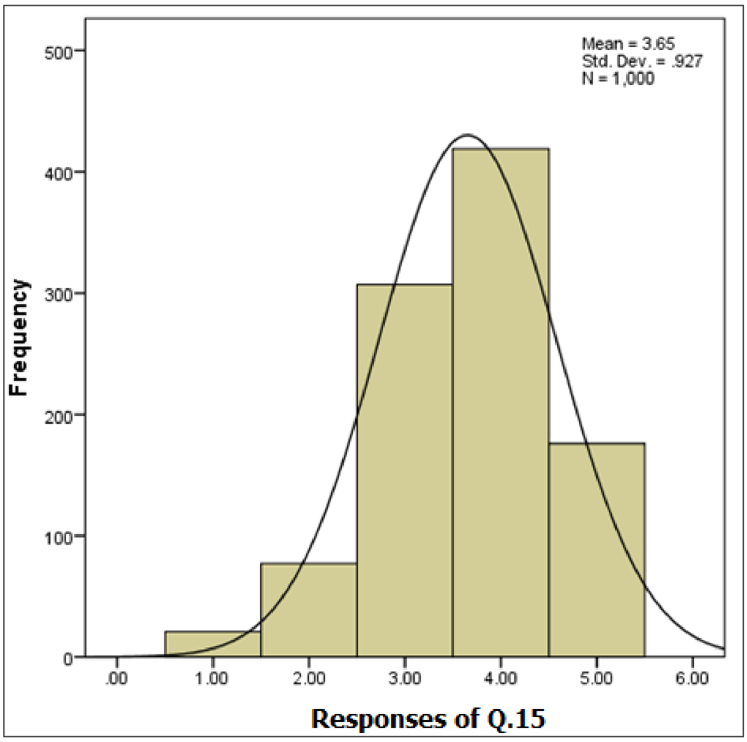

Figure 6. Responses about Reducing Accidents versus Frequency

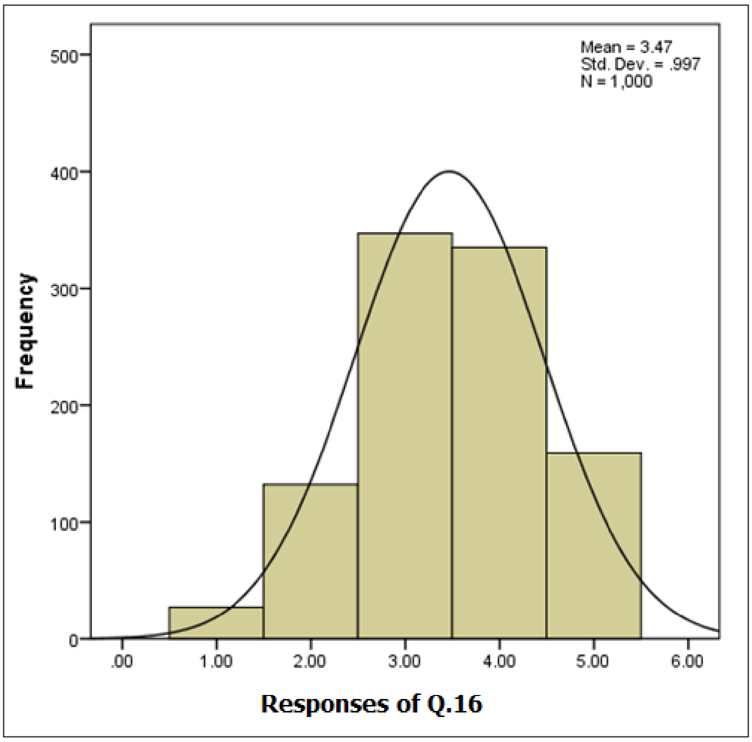

Figure 7. Responses about the Effectiveness of Warning Signs versus Frequency

To assess the effectiveness of the municipalities in law enforcement and preventing the erection of speed humps without authorization, the responses were analysed and the weighted average of responses was 2.16 as in Figure 8. Noting that the highest frequency ratio was 36.7% "low effect" followed by a frequency ratio 29.4% "very low effect" as in Table 7.

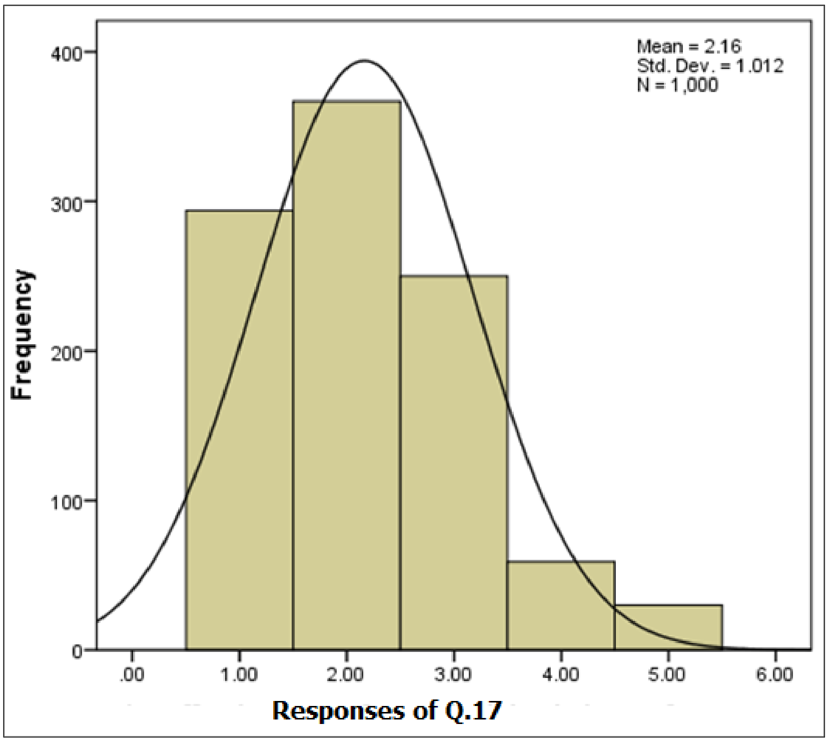

Figure 8. Responses about the Effectiveness of Municipalities in Preventing Establishment of Speed Humps versus Frequency

By comparing the results of the analysis of the responses on the flow of traffic before and after the erection of speed humps, it turned out that the weighted average decreased from 3.77 to 2.8 as shown in Figure 9 and Figure 10. Regarding the flow of traffic before the erection of humps, it is noted that the highest frequency ratio of responses was 53.8%

"high" followed by a frequency ratio 26.3% "medium" as in Table 7. While in terms of the flow of traffic after the erection of humps, the highest frequency ratio of responses was 52.5% "medium" followed by a frequency ratio 28.7% "low" as in Table 7. This confirms that the installation of speed humps significantly reduces the flow rate of traffic.

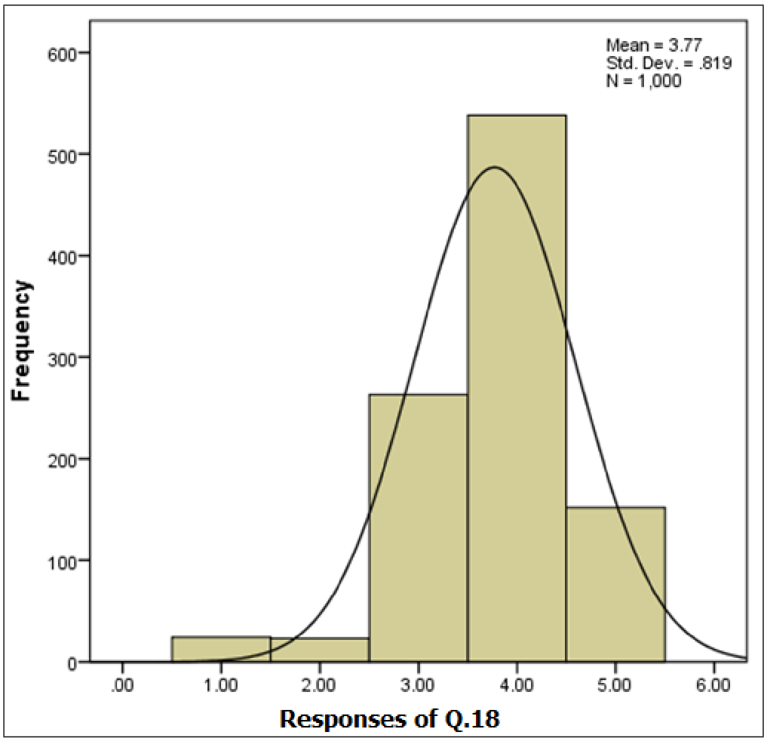

Figure 9. Responses about flow of traffic before the erection 0f the hump versus frequency

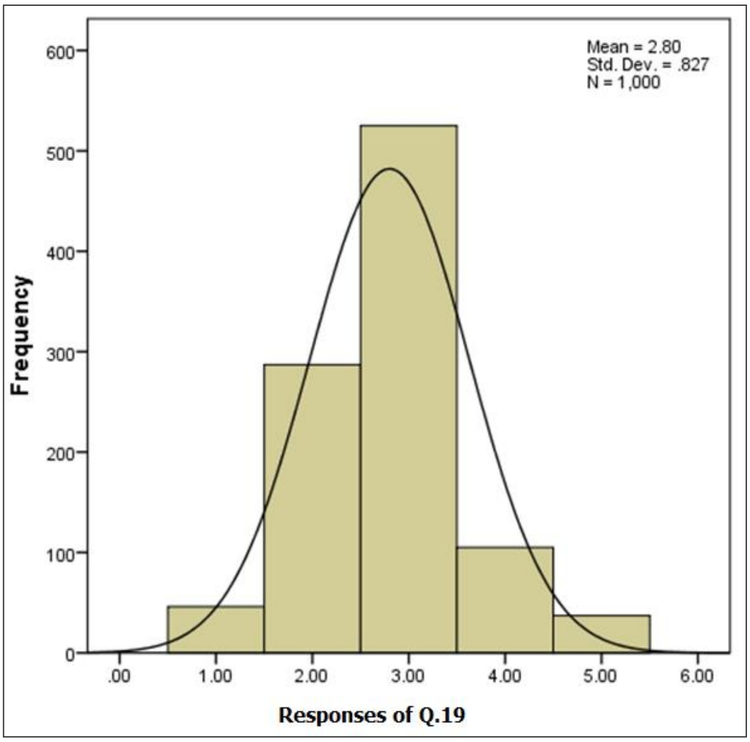

Figure 10. Responses about Flow of Traffic after the Erection of the Hump versus Frequency

By comparing the results of the analysis of the responses on the speed before and after the erection of speed humps, it turned out that the weighted average decreased from 4.23 to 2.75 as shown in Figure 11 and 12. Regarding the speed before the erection of humps, it is noted that the highest frequency ratio was 49.5% "high speed" followed by a frequency ratio 38% "very high speed" as in Table 7. While in terms of the speed after the erection of humps, the highest frequency ratio was 50.2% "medium speed" followed by a frequency ratio 28.4% "low speed" as in Table 7. In the end, this means that speed has decreased significantly due to the installation of speed humps.

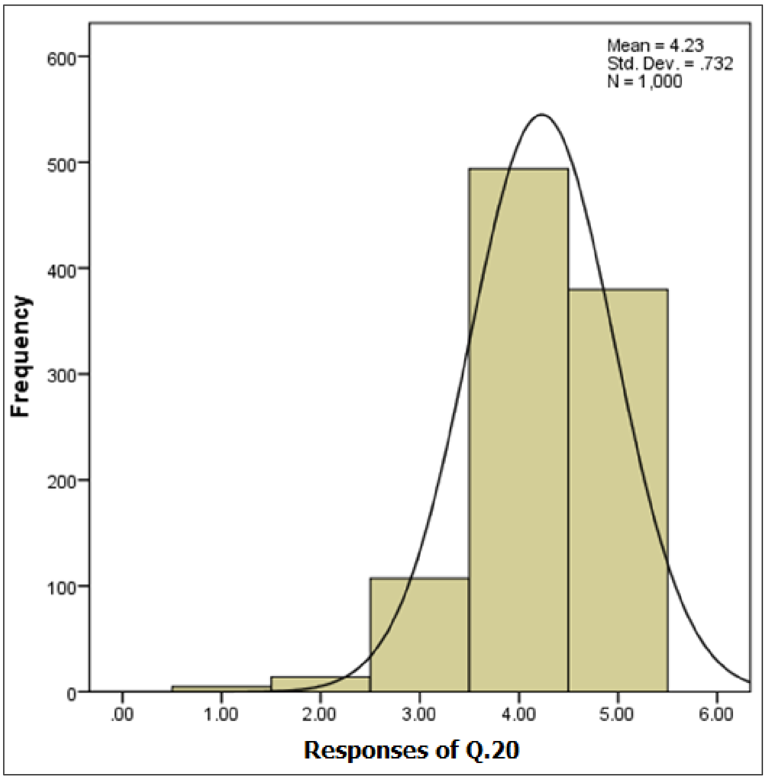

Figure 11. Responses about the Speed before the Erection of the Hump versus Frequency

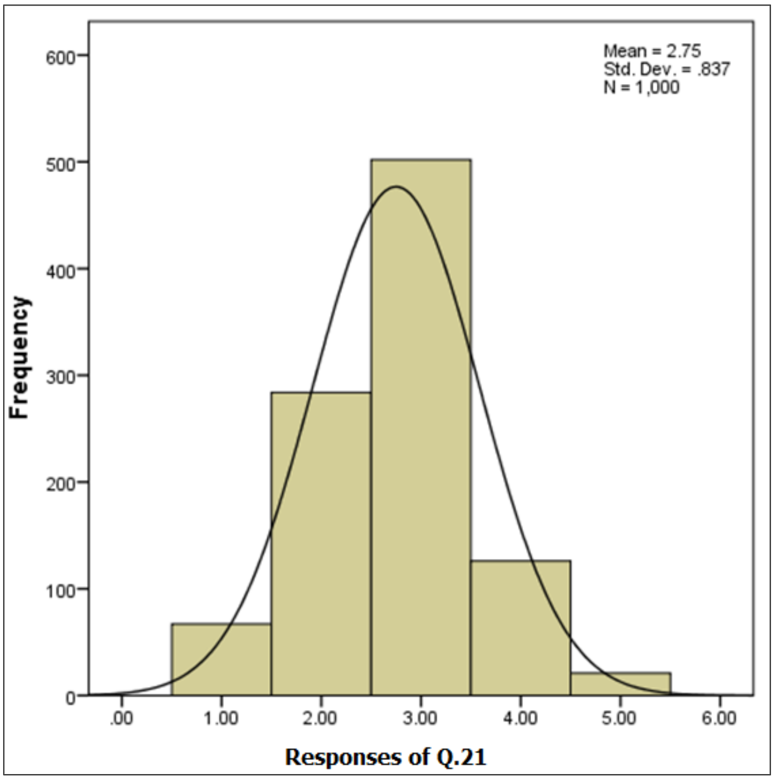

Figure 12. Responses about the Speed after the Erection of the Hump versus Frequency

Regarding warning signs and markings, 84.8% of the participants reported that there were no warning signs before the humps sites and 83.6% of the participants reported that there were not any markings on the surface of the humps in the areas under study as in Table 8.

Table 8. Road Signs and Markings of the Humps

Question number	Choices	Frequency	Percent (%)
Q22	Yes	152	15.2
	No	848	84.8
Q23	Yes	164	16.4
	No	836	83.6

Where [Q22-Q23] are indicated in the questionnaire given in Appendix (I)

Based on the results of this study, regarding the positive effects of using speed humps in controlling the traffic. It is considered an effective mean of reducing vehicles speed, which greatly contributes to reducing the rate of accidents in the vicinity of hump location

So, it is very necessary for the roads directorates to follow a generalized standard and specification to control the installation of speed humps in order to achieve the desired purpose. This specification should give geometric hump characteristics and locations where speed humps should be installed. On the other hand, warning signs and reflective marking guidelines should be executed. A strict law must be observed to stop installation of a new hump without obtaining a permit from the relevant authorities. Also, attention should be given to the periodic maintenance of pavement surface in the vicinity of the humps locations and the phosphorous markings should be used so as to decrease the potential occurrence of accidents especially at night.

The use of speed humps leads to significant economic costs due to the maneuvering (deceleration, overtaking and acceleration over a hump), loss of time, vehicle deterioration, pavement defects in the area of the hump. In addition, these speed humps result in high fuel consumption of moving vehicles. Certainly, suitable design profiles of speed humps should be used to minimize potential damage to both vehicles and pavement surface.

Speed humps also contribute significantly to the environmental pollution. The increase of noise in the vicinity of the speed hump location can be noticed from intensified braking and acceleration. Vehicles emissions increase dramatically because of speed reduction and irregular patterns of movement. Also, at hump location, the surrounding area may be severely damaged as well as rain gutters frequently filled with waste which block the drainage pipes.

Finally, the use of speed humps can cause many harmful effects to the neighborhood, if there no strict control on its installation process. Unless standard specifications and strict regulations are followed, other means of traffic calming measures should be considered.

6. Conclusions

The most important findings of this paper can be outlined as follows:

- The responses showed that a large percentage of road users believe it is important to install speed humps at educational/school places, hospitals and before intersections. On the other hand, 42.6% of the respondents reject the installation of humps at the commercial places as well as 50.4% of the respondents reject the installation of humps before horizontal curves.
- Based on the responses received from the drivers, vehicle owners and vehicles' repairmen to evaluate the cost of potential vehicle breakdowns due to humps, it was found that the average cost of the repairing is approximately $ 200 per year.
- By comparing the responses on vehicle speed before and after installation of humps, it was found that speed decreased significantly after the installation of humps.
- By comparing the responses on traffic flow rate before and after installation of humps, it was found that the traffic flow rate decreased significantly after the installation of humps.
- With regard to the effectiveness of speed humps in reducing the accident rate, the responses showed that their effectiveness is high in reducing the accident rate. Consequently, speed humps are a very effective mean to enhance traffic safety.
- With regard to the effectiveness of municipalities in law enforcement and preventing the installation of speed humps without permission from relevant authorities, the responses showed that their effectiveness is very low in preventing the installation of illegal humps. So much more effective law should be applied in order to prevent the installation of illegal humps.
- The majority of responses confirmed that the use of warning signs along the road is an effective way in controlling the flow of traffic. In spite of that, more than 80% of the participants reported that there were no warning signs before the locations of humps. This means that a number of drivers can collide with the speed humps suddenly,

especially during the night, since there is no enough lighting for most roads.

- According to the results, there are several environmental effects associated with the installation of humps.
- 73.6% of the respondents believe that the humps cause additional noise when the vehicles pass over humps. This causes inconvenience to road users and residents near the area of the humps.
- 68.6% of the respondents believe that the installation of speed humps contributed greatly to the environmental pollution by increasing the emission rate of exhaust, which is very dangerous to public human health.
- 60.3% of the respondents believe that if the rain gutters was blocked with waste, this leads to water retention behind the humps that may adversely affects the pavement condition in the vicinity of speed humps.

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8. Appendix I

QUESTIONNAIRE

This questionnaire is to study the performance and effectiveness in Kafr El-Sheikh urban area in Egypt from the public point of view. It is designed specifically for academic purposes only. And it does not interfere with the privacy and security of the individual respondents. Your cooperation in helping us provide the information below will be greatly appreciated. Thank you very much. Choose the appropriate answer as required below.

	Do you think that the installation of speed humps leads to?	
Section 1	(Q1) Reduce excess speed?	
	Yes	No
	(Q2) Accidents caused by wrong overtaking?	
	Yes	No

	Do you think that the humps should be installed at the following places?	
Section 2	(Q3) Educational institutions	
	Yes	No
	(Q4) Trade places	
	Yes	No
	(Q5) Hospitals	
	Yes	No

	(Q6) Before non-signalized intersections				
	Yes		No		
	(Q7) Before horizontal curves				
	Yes		No		

Section 3	**Does the presence of speed humps lead to? (Environmental impact)**				
	(Q8) Noise				
	Yes		No		
	(Q9) Increase the emission rate of exhaust				
	Yes		No		
	(Q10) Destruction of the surrounding area				
	Yes		No		
	(Q11) Fill the rain gutters with waste				
	Yes		No		

Section 4	**What is the impact of speed humps on? (Economic impact)**				
	(Q12) Vehicle breakdowns				
	Very low	Low	Medium	High	Very high
	(Q13) Paving damage before and after hump location				
	Very low	Low	Medium	High	Very high
	(Q14) Evaluate the cost of potential vehicle breakdowns due to humps.				
	Very low	Low	Medium	High	Very high

Section 5	**(Q15) The effectiveness of the speed hump to reduce the number of accidents**				
	Very low	Low	Medium	High	Very high
	(Q16) How effective are warning signs in controlling traffic flow?				
	Very low	Low	Medium	High	Very high
	(Q17) The effectiveness of municipalities in law enforcement and preventing the establishment of speed humps without authorization				
	Very low	Low	Medium	High	Very high
	(Q18) Flow of traffic in the area before the installation of speed humps				
	Very low	Low	Medium	High	Very high
	(Q19) Flow of traffic in the area after the installation of speed humps				
	Very low	Low	Medium	High	Very high
	(Q20) Speed in the area before the installation of hump				
	Very low	Low	Medium	High	Very high
	(Q21) Speed in the area after the installation of speed hump				
	Very low	Low	Medium	High	Very high
	(Q22) Are there any warning signs before the location of the hump in your area?				
	Yes		No		
	(Q23) Are there any markings on the surface of the humps in your area?				
	Yes		No		