THE EFFECTIVENESS OF TRAFFIC CALMING MEASURES IN THE CAMPUS OF UNIVERSITI TEKNOLOGI PETRONAS: ROAD HUMPS

by

Ida Raihana Izzati binti Nor Azelin
15354

Dissertation submitted in partial fulfillment of
the requirements for the

Bachelor of Engineering (Hons)
(Civil Engineering)

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Universiti Teknologi PETRONAS
Bandar Seri Iskandar
31750 Tronoh
Perak Darul Ridzuan

CERTIFICATION OF APPROVAL

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Approved by,

____
(Assoc. Prof. Dr. Madzlan Napiah)

Universiti Teknologi PETRONAS

Bandar Seri Iskandar

31750 Tronoh

Perak Darul Ridzuan

September 2015

CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is my own except as specified in the references and acknowledgements, and the original work contained herein have not been undertaken or done by unspecified sources or persons.

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IDA RAIHANA IZZATI BINTI NOR AZELIN

ABSTRACT

Traffic Calming Measures are compilation of acts done to reduce vehicle speed, to ensure the safety of road users and also to ease the residents nearby live in a tranquil environment. The most effective traffic calming measure is road hump as it involves vertical deflections in the carriageway. Due to excessive number of vehicles and speeding issue in campus, this study is conducted to investigate on the effectiveness of road humps in the campus of Universiti Teknologi PETRONAS, Perak. The suitability of the design of existing road humps will be re-evaluated. From this, the optimum traffic calming measures can be done to improve the current traffic conditions. Spot Speed is measured at places in campus with and without the existence of road humps to investigate whether the speed limit within the campus which is 40 km/h is complied. Questionnaires are also distributed to the community of different ages and status in the campus. Hence, the effectiveness of road humps is determined. Results from the questionnaires shows that majority of students agree that road humps do help in reducing vehicles speed although it causes discomfort to them due to the excessive number of it. However, majority confessed that they would not abide by the speed limit without the existence of road humps. This is further verified by results from Spot Speed Survey. Evidently, road humps help in reducing the average speed of vehicles in the campus and making sure the speed limit is complied

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Table of Contents

LIST OF FIGURES

LIST OF TABLES

CHAPTER 1

INTRODUCTION

1.1 Background of Study

According to Gupta (2014), Traffic Calming incorporates physical design and other measures, such as speed humps and traffic circles to slow down the speed of traffic as well to improve safety for pedestrians and cyclists. Traffic calming is done for safety concerns, to reduce the need for enforcement and also as per requests by the citizens. The effectiveness of traffic calming can be established with the reduction in the average speed of vehicles on the road. The most effective measure is road humps as it involved vertical shifts in the carriageway.

The speed limit of vehicles in the campus of Universiti Teknologi PETRONAS (UTP) is 40 km/h. The speed limit is enforced with the intention to improve road traffic safety, to reduce the number of road traffic casualties from traffic collisions, and to reduce the environmental impacts which includes noise and air pollution from vehicles. To ensure that the speed limit is complied by the community in the campus, road humps are placed so that vehicular speed can be reduced to an acceptable speed.

This study aims to study on the effectiveness of road humps in the campus of UTP by doing Spot Speed Survey and also data collection of the community in the campus. The effectiveness of road humps can be measured with reduction in the mean speeds, reduction in the 85th percentile speeds, reduction in the highest speeds, reduction in the number of complaints, reduction in the statistics of road accidents and positive response by the public.

1.2 Problem Statement

Unlike other university, there were no rules in UTP against new students bringing vehicles into the campus. This translated in the excessive number of vehicles in the campus. The ratios of total number of students to the number of students who possess vehicles are 3:1. This leads to traffic congestion. Excessive number of vehicles contributes to traffic casualties due to vehicular collisions.

Speeding also is one of the issues in UTP. Students tend to accelerate in a hurry to go to class, especially. As the speed of vehicles increase, the reaction-time will be delayed. Hence, the impact of collision on the human bodies will be worse. As a result, speeding could attribute to fatal injuries, which is a serious concern.

Hence, traffic calming measures such as road humps are implemented to resolve these issues.

1.3 Objective

While conducting this study, literature reviews on the traffic calming projects that had been conducted by others are reviewed. It was found that those projects reviewed the works of multiple traffic calming measures simultaneously. Hence, it is strenuous to assess the effectiveness of the individual traffic calming measures. Thus, this study is implemented to achieve the following objectives:

- To evaluate the effectiveness of traffic calming measure which is road hump in UTP campus
- To assess the suitability of the designs
- To recommend the optimum traffic calming measures to road in UTP campus
- To increase the number of data available to decision-makers and interested individuals in which it can be used by the management of UTP

1.4 Scope of Study

The scope of this study shall involve:

i. Reconnaissance Survey

   Reconnaissance survey is a detailed examination of all part of an area to obtain the data for the existing road humps. It is done to gather initial information regarding road humps which includes maps of the location and photographs. The results can be used to determine whether the design met the specifications outlined by the Highway Planning Unit (HPU), Ministry of Works Malaysia.

ii. Spot Speed Study

   Spot Speed Study is used to determine the distribution of traffic speeds, at specific location. The speed of vehicles is spotted using a radar gun. The location of study will be at multiple roads in UTP campus with existing road humps, and also at road with no road hump. The average speed at both locations can be discovered.

iii. Questionnaires

   In survey research, a questionnaire is an instrument that is comprised of a set of questions to be asked to the participants of the survey. In this study, questionnaires will be distributed to community which is constituted by the students, lecturers and also non-academic staffs to obtain the feedback regarding the effectiveness of the existing road humps. The feedback will be used to improve on the existing road conditions of UTP campus.

1.5 Relevancy and Feasibility

Safety is the main concern in any aspect of life. Traffic Calming Measures is designed to enable community support for traffic education, facilitate the identification of specific traffic concerns, collect data, develop solutions, and evaluate the impact of these solutions. The primary focus of any initial traffic calming changes will be to change driver behavior, and doing so with tools that tend to be less controversial and less expensive.

Through appropriate use of Traffic Calming, the probability and severity of accidents can be reduced. Thus, it increased the safety of road users and also the people who live nearby to the roads.

This study aims to evaluate the effectiveness of the existing road humps in the campus of UTP. This study was commenced at the late of May 2015 and aims to collect quantitative data (through Spot Speed Study) and qualitative data (through questionnaires). The time frame is feasible and the project can be completed within the allocated time.

CHAPTER 2

LITERATURE REVIEW

2.1 Traffic Calming

The origin of Traffic Calming comes from Dutch "Woonerf" schemes in the 1960's, and since then has been further developed and cultured throughout northern Europe, explicitly in Germany and the Netherlands, (Lines and Castelijn, 1991). The residents of the Dutch City of Delft began a grassroots movement as they fought cut-through traffic by changing their streets into "woonerven", or "living yards" (Pharaoh and John, 1989). Hence, the street became a co-area between vehicles' users and the residents where it is equipped with benches, parking bays and pedestrian path.

However, woonerven was not convenient in the long term as it was designed for areas with low volume traffic. As the volume of traffic increased, a solution need to be done to mitigate this issue. Out of all approaches proposed, the traffic calming alternative was judges as the most cost-effective for neighborhood streets (from pp. 1 of the *Brief History of Traffic Calming*).

The Institute of Transportation Engineers (ITE) (1997) defined Traffic Calming as the integration of physical means that minimize the negative impacts of vehicles. It also helps to, voluntarily and involuntarily; change the attitude of drivers thus making the road safer for the non-motorized users. There are 3 E's that traffic engineers are often concerned with when discussing traffic calming, which is Education, Enforcement, and Engineering (Montgomery County, Maryland, trafficcalming.org). By the enforcement of speed limit on roads alone does not result in reduction of vehicles speed (O'Connor, 1999) as drivers typically drive at the speed of what they perceived as safe according to the road condition and weather. Hence, the implementation of traffic calming measures will naturally force the road users as they react to the physical existence of traffic calming device.

2.2 Types of Traffic Calming

Traffic Calming can be divided into 4 types which are:

- **Vertical Measures** – Reduce speed using vertical deflection
- **Horizontal Measures** – Reduce speed using horizontal deflection
- **Road Narrowing –** Another form of vertical measure but it does not reduce speed in itself, instead it acts as a reminder for drivers to drive slowly
- **Central Islands** – Reduce speed by installation of traffic islands along the center of the road

2.2.1 Vertical Measures

Harvey T. (n.d.) in his research paper mentions that vertical shifts in the carriageway are the most effective and reputable of the speed reduction measures presently available. Examples of vertical measures are:

a) Road Hump

Road hump is an elevated areas positioned across the roadway to reduce speed. Its shape can be rounded, flat-topped and parabolic (Brown, 2011). Figure 1 shows an example of rounded road hump.

FIGURE 1: Road Hump (The Post and Courier, 2015)

b) Plateau

Plateau, also known as speed table is a revised speed hump with a flat top as shown in Figure 2 which enable the wheelbase of a passenger car to rest or lay on top. It provides a milder slope than speed humps, but less reduction in speed can be expected (Brown, 2011). According to Harvey T. (n.d.), plateau extends the full width of the carriageway between the curbs and extends over a longer length of road than road humps. The surface should be of different material to the carriageway and footways.

Plateau is more fitting than road humps when the measures are implemented on bus routes. The length of the plateau should be adequate to accommodate the full wheelbase of the bus to reduce passenger discomfort to a minimum (as cited in "*Local Authorities Go It Alone on Speed* Cushions", 1992, p. 9).

FIGURE 2: Plateau also known as Speed Table (Dan Burden, 2010)

c) Speed Cushions

Brown (2011) explained that speed cushion is several small humps positioned across the width of the road with gaps between them. It is installed in a series across a roadway mirroring a split speed hump as shown in Figure 3. Speed cushion is invented to physically force cars to slow down as they ride with one or both wheels on the humps. Emergency vehicles with wider axles are able to pass through the cushions without affecting their speed.

FIGURE 3: Speed Cushion (www.rosehillhighways.com)

d) Rumble Strips

According to U.S. Department of Transportation Federal Highway Administration, rumble strips, as shown in Figure 4, are an effective measure to reduce roadway departure crashes. The noise and vibration produced by rumble strips alert drivers when they leave the traveled way.

FIGURE 4: Rumble Strips (Government of Western Australia, 2015)

2.2.2 Horizontal Measures

Research by Harvey T. (n.d.) supports Kent County Council Highways and Transportation Department which said horizontal deflections in the carriageway are less effective than vertical measures in achieving the reduction in speed. Examples of Horizontal Measures are:

a) Traffic Circles

According to Brown D. (2011), traffic circle is an elevated island in the middle of an intersection around which traffic flows, as depicted in Figure 5. It is built to avert speeding by making it difficult for vehicles to pass straight through intersections. A truck apron could be added to facilitate movement through the intersection by larger vehicles.

The minimum diameter should be 24 feet; 26 to 33 feet is preferred. It is often used on roads with lower speed (Brown, 2011).

FIGURE 5: Traffic Circles (www.pedbikeimages.org)

b) Roundabout

Based on research paper by Brown D. (2011) roundabout is a much larger variant of a traffic circle that allocates yield control to all incoming vehicles and channelized approaches to support a higher Average Daily Traffic (ADT) of more than 20, 000. It is generally formulated to prompt travel speeds to be less than 30 mph but can have more than one travel lanes as portrayed in Figure 6. Its diameter ranges from 45 to 200 feet.

FIGURE 6: Roundabout (NYC: Department of Design and Construction, 2014)

c) Chicanes

Chicanes are curb extensions that generate an S-shaped curve on a street, as depicted in Figure 7. Its effectiveness is not promising as a driver can preserve speed and drive down the centerline if there is no entering traffic (Brown, 2011).

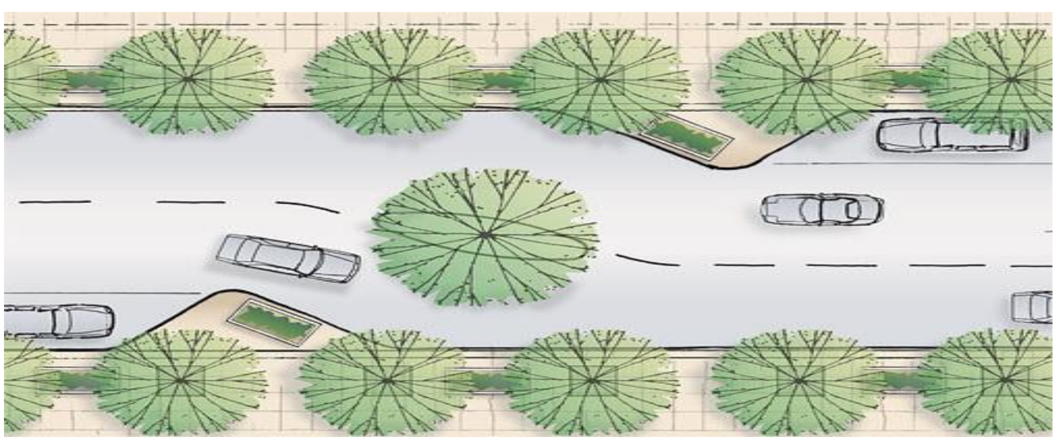

FIGURE 7: Chicane (www.sfbetterstreets.org/, 2011)

2.2.3 Road Narrowing

Road narrowing is a measure on which the carriageway is narrowed at specific locations. On narrowed two-way roads occasional strips at the edge of the carriageway may be used to enable big vehicles to travel. If these are built in sets or similar materials, car drivers will shun away from using them (Harvey, n.d.)

He also mentioned that the additional space generated from road narrowing is typically used to improve traffic facilities such as footways widening, dedicated cycle ways and parking bays.

2.2.4 Central Islands

According to London Borough of Sutton, Central Island is a traffic island installed at the center of the road to reduce speed as well as acting as a pedestrian facility to cross the road. The installation of Central Island is proven to be effective to prevent overtaking. It also does not affect the travel time of emergency vehicles. Figure 8 is an example of a central island.

FIGURE 8: Central Islands (Land Transport Authority, n.d.)

Table 1 concluded that road hump is the most effective traffic calming measures as it reduces the traffic flows by 25% and it also results in the highest injury reduction of about 60%.

Table 1: Summary of Measures and Their Relative Performance (www.trl.co.uk/molasses)

type of measure		impact on			
		traffic speeds	traffic flows	injury accidents	bus/emergency routes
speed calming measures [a]	road hump	Speeds are influenced by vehicle type* and hump dimensions. Speeds between humps are influenced by 'before' speed, hump spacing and dimensions.	Reductions in traffic flows on average by 25 per cent.	Reductions in injury accidents of about 60 per cent**.	Journey times for buses and delay for emergency services can increase; user discomfort in bus/ambulance can be usually higher than in cars.
speed calming measures [a]	mini-round about	Speeds depend on deflection size (the bigger the deflection, the lower the speed).	Inclusion within a traffic calming scheme will not greatly affect vehicle flows.	Reductions in injury accidents on average by 40 per cent.	Reductions in delays to emergency services
speed calming measures [a]	chicanes	Effective speed control device, but not quite as effective as road humps. May not reduce speeds of two-wheeled motor vehicles.	May remove some through traffic but effects on traffic flows may be small (about 7–15 per cent overall) May cause localized congestion on roads with high traffic flow, if dimensions are too restrictive.	Reductions in injury accidents on average by 47 per cent*** Collisions with the kerb build-outs may increase both damage-only and injury accidents.	Less delay to fire appliances. Discomfort may be experienced by passengers in buses and ambulances, depending on vehicle type, vehicle speed and chicane dimensions.
traffic intrusion measures [b]	pinch point	Carriageway width is restricted so that only one vehicle at a time may pass (or two cars can pass slowly).	Medium reduction in traffic flows	Medium reduction in injury accidents	High reductions in delays to emergency services

[a] Speed calming measures aimed at reducing traffic speeds also include raised pedestrian crossing.
[b] These measures also include semi- closures and full closures. Detailed studies are required to ensure that street closures will not result in traffic intrusion problems in other areas.
(*) Buses, ambulances and commercial vehicles over humps cross at a slower speed than cars.
(**) In 20 mph zones and on 30 mph roads in UK.
(***) Accident data from MOLASSES (web page: www.trl.co.uk/molasses)

2.3 Road Humps

Johnson L. T. and Nedzesky A. J. in their research paper remarked that as the traffic calming measures evolve throughout the U.S., the usage of road humps as traffic calming device has been steadily escalated. This is because as explained by Ewing (2001), the fondness to road humps comes from the points that they are cheap to construct and are more effective in reducing speed and accidents, as depicted in Table 1.

In 1997, the Institute of Transportation Engineers (ITE) approved the *Guidelines for the Design and Application of Speed Humps*, RP-023A, which provided recommended practice based on national and international research and experience. ITE published that speed humps should be installed on roadway facilities classified as local streets by the American Association of State Highway and Transportation Officials (AASHTO). Criteria for locations of road humps are as listed in Table 2.

Table 2: Locations of Road Humps (Institute of Transportation Engineers, Washington DC*;* www.ite.org)

Locations Recommended To Be Installed	Locations Should Be Avoided
Urban areas i.e; streets with closed drainage (storm sewer) and curbs.	On arterial roads, roads with through traffic, roads frequently traveled by public transit, trucks or emergency vehicles, and roads with four more lanes.
Streets with little through traffic that are not regular public transit, emergency vehicle or trucking routes.	In curves or approaches to curves, on roads with a particularly pronounced slope or locations where road humps would not be sufficiently visible or could surprise drivers.
Residential streets, school zones and playground zones.	Sectors where the 85th percentile speed is above 70 km/h.
Sectors where the speed limit is 50 km/h or less.	On approaches to intersections.
Sectors where low speeds are desired (around 30 km/h)	Before a driveway.

Table 3 is a recommendation of design by ITE. As for the length, ITE recommended 12 feet.

Table 3: Height Design of Road Humps According to Speed (Institute of Transportation Engineers, Washington DC; www.ite.org)

Height	Speeds
3 inches	20 – 25 mph
4 inches	15 – 20 mph

Berthod C. (2011) in her research paper mentioned on the requirements for road humps, which are:

- To leave gaps of approximately 0.6 m on each side of the curb for the cyclist and motorcycle to pass through. The gaps on each side also have to be sloped for good drainage system.
- To ensure good lighting so that the road humps are visible to road users
- Markings on road humps along with signage are compulsory, as portrayed in Figure 9
- Removable road humps must be carefully affixed to the road to prevent them from being ripped off

FIGURE 9: Road Marking and Signage on Road Humps (Government of Western Australia, 2015)

2.4 Types of Road Humps

According to Layfield R. and Webster D. (n. d.), there are two types of road humps which are **round-top humps** and **flat-top humps**. Table 4 described the dimension specifications of both humps.

Table 4: Dimension Specifications of Road Humps (Highway Planning Unit, Ministry of Works Malaysia, 2000)

	Flat-Top Hump	Round-Top Hump
Width	2.5 m – 4.0 m	3.7 m – 4.0 m
Height	75 mm – 100 mm	50 mm – 100 mm

Figure 10 and Figure 11 shows the profiles for both round-top humps and flat-top humps.

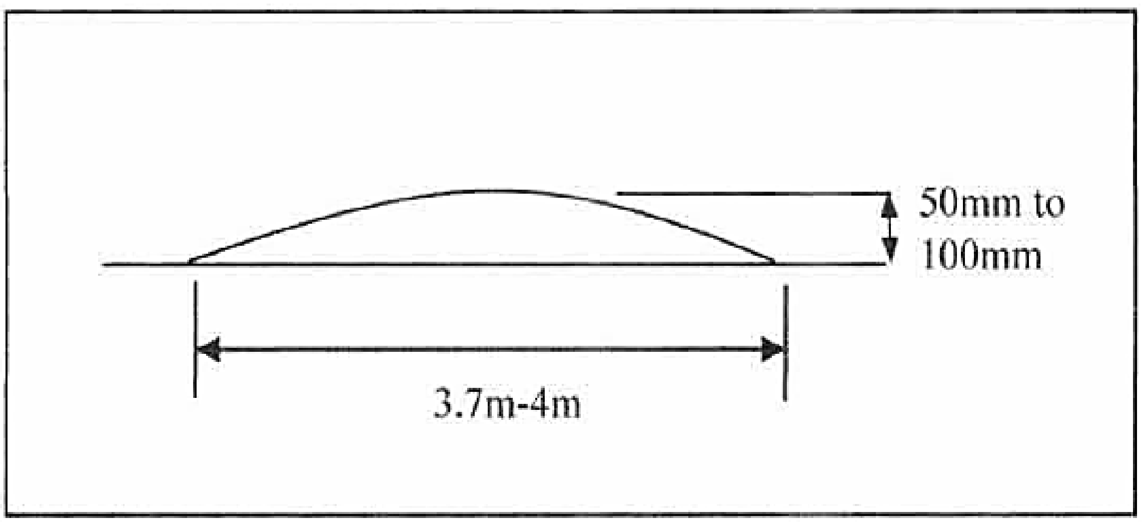

FIGURE 10: Round-Top Humps Profile (Highway Planning Unit, Ministry of Works Malaysia, 2000)

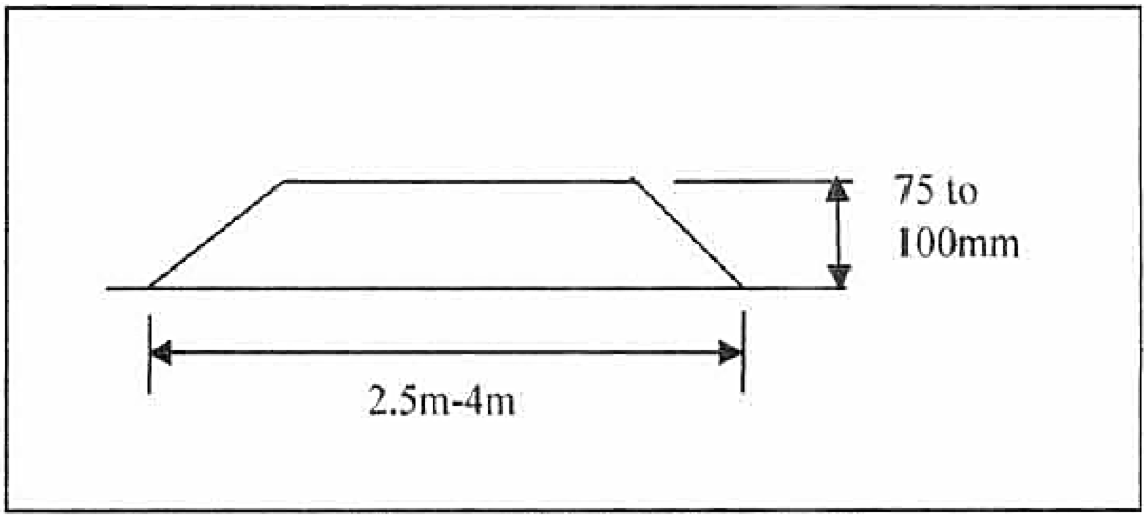

FIGURE 11: Flat-Top Humps Profile (Highway Planning Unit, Ministry of Works Malaysia, 2000)

Flat-top humps are easier to construct and to maintain. Later, they are used as pedestrian crossing.

2.5 Impacts of Road Humps

2.5.1 Impacts on Speeds

Berthod C. (2011) remarked that the installation of road hump helps reducing driving speeds. The results differ depending on the length and height of hump. It is noted that round-top hump resulted in a lower vehicular speed compared to flat-top speed which resulted in a higher driving speed.

However, road hump has little to no effect in controlling the speed of two-wheeled vehicles, which can pass through the road at the curb without contacting the road humps (Berthod, 2011).

2.5.2 Impact on Road Safety

Reducing traffic speeds can reduce the number or collisions and its severity of vehicle and also road users (Kloeden C. N., McLean A. J., Moore V. M., and Ponte G., 1998). Each 1-mph traffic speed reduction typically reduces vehicle collisions by 5%, and fatalities by an even greater amount as proven in Figure 12.

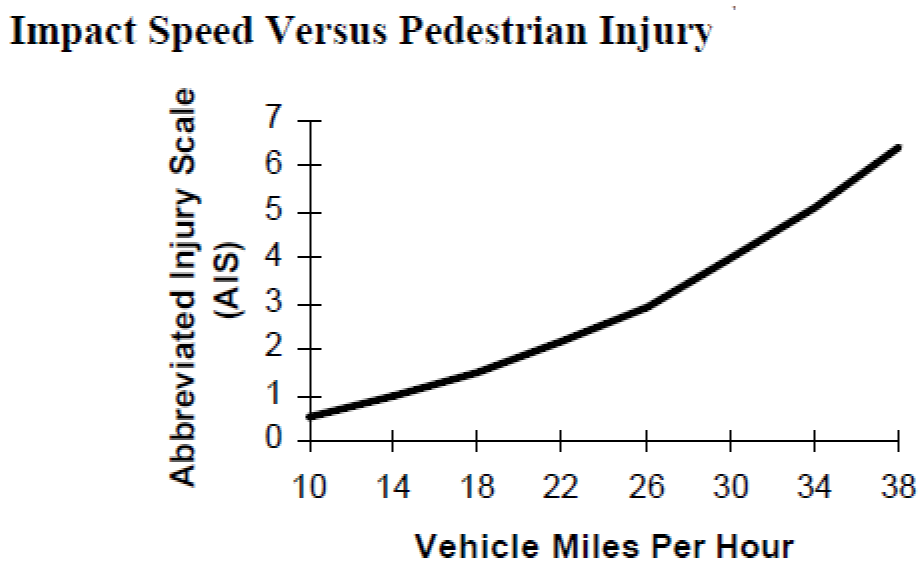

FIGURE 12: Graph of Impact VS Pedestrian Injury (Institute of Transportation Engineers, Washington DC*;* www.ite.org)

Figure 12 shows that risk to pedestrians and cyclists increases with vehicles speeds. Other researchers conclude that small reductions in travel speeds lead to large reductions in impact speed in pedestrian collisions, often to the extent of preventing the collisions altogether (from *Accident Analysis and Prevention*, Vol. 29, No. 5, 1997, pp. 667-674).

Hence, road users and residents will feel a lot safer and this will improve the living conditions of the residents.

2.5.3 Impact on Noise

According to the Department of The Environment, Transport and the Regions, UK (1996), Traffic Calming generally reduce traffic noise. Reduction in vehicle speeds from 50 to 30 kph will results in reduction of 4-5 decibels.

However, it is a different case with road humps. Sure, by lowering the vehicles speed will lower the noise emission level (Layfield and Webster, n. d.). Nevertheless, vehicle noise emission will depend on the driving style; a calm driver or a passive driver. The uses of excessive braking and deceleration and acceleration of vehicles might contribute to a high noise emission.

2.5.4 Impact on Air Pollution

As the installation of traffic calming leads to lower traffic volumes, this will typically reduce exhaust emission and reduce air pollution. However, similar to impact of traffic calming to noise, exhaust emission also depends on the behavior of drivers.

As stated by Layfield R. and Webster D., as aggressive drivers tend to drive with high proportion of acceleration and deceleration, this will result in high exhaust emission. Compared to calm drivers, which drive across a road hump in a high gear as possible, this will result in relatively low emission and reduce air pollution as shown in Table 5.

Table 5: Effects of 50 to 30 kph Speed Reduction (*Transportation Research Board/National Academy Press* (Washington DC; www.nas.edu/trb), 1995, p. 369)

	Calm Drivers	**Aggressive Drivers**
Carbon Monoxide	- 13%	- 17%
VOCs	- 22%	- 10%
NOx	- 48%	- 32%
Fuel Use	- 7%	+ 7%

CHAPTER 3

METHODOLOGY

3.1 Literature Review

Journals related to *Traffic Calming* and *Road Humps* are used to collect the relevant information regarding this study which is to investigate the effectiveness of road humps in UTP campus. Most of the references used are from the Highway Planning Unit, Ministry of Works, Malaysia and also from the Institute of Transportation Engineers. References from this study can be referred on the Reference Section of this paper.

3.2 Reconnaissance Survey

A reconnaissance survey provides data that enables design engineers to study the physical features of study area. A map of UTP campus is used to identify the locations of road humps in UTP. From this, the suitable locations for the study area can be determined to carry out Spot Speed Survey. Photograph evidences will be useful to study on the physical features of the road humps on selected study areas.

3.3 Spot Speed Study

In this method, the speed of vehicles at selected locations will be determined by using radar gun. For this study, the spot speed data will be collected at locations with existing road humps and also at locations with no road humps. This is done to determine on the effectiveness of the road humps. This will also help to determine whether the roadway is in need of new law enforcement, realignment, or reconstruction.

For this study, survey will be done at six locations; 3 locations with the existence of road humps and 3 locations with no road humps. The chosen locations will be at:

1. In front of the cafe of Village 2 (road hump)
2. Roadway from Chancellor Hall to UTP mosque (road hump)
3. Before junction to Gate 3 (road hump)
4. Road behind Block 1 and Block 2 (no road hump)
5. The road beside Village 4 Soccer Field (no road hump)
6. The road from Gate 3 to Pocket C (no road hump)

The survey will be conducted during weekdays and weekend and special occasion and holidays will be avoided to determine the maximum number of vehicles during normal hours and peak hours. This is for better consistency.

For the location with existing road humps, three points will be marked on the road as illustrated in Figure 13. Using radar gun, the speed of vehicles at each marked points along the travel path will be captured.

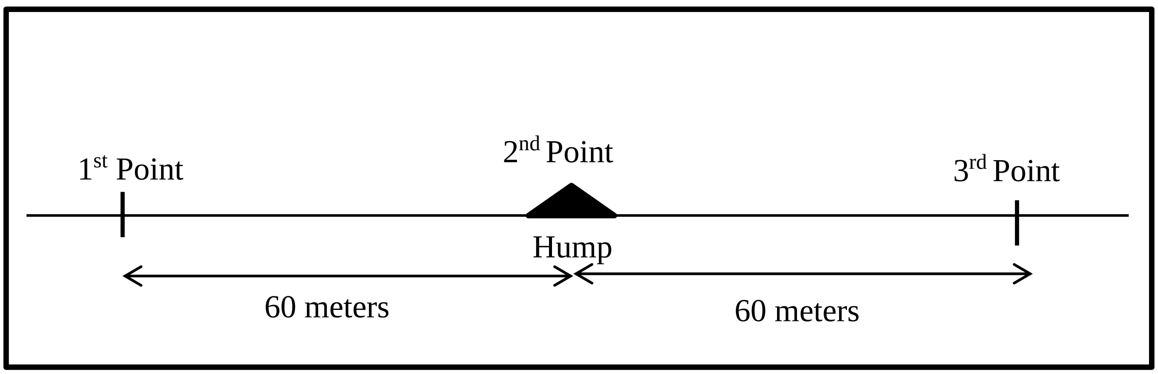

FIGURE 13: Process of Spot Speed Study

As illustrated in the Figure 13, the speed of vehicles will be determined at three points; speed of vehicles approaching road hump, speed of vehicles on road hump, and speed of vehicles leaving the road hump.

While for locations with no road humps, the speed of vehicles will be captured at one point only. The survey will be conducted for passenger cars only. The results for this survey will be used in constructing vehicles speed profiles.

3.4 Questionnaires

A set of questions is distributed to the community of UTP which consists of students, academic staffs, and non-academic staffs. The purpose of this survey is to obtain feedback on the opinions of the existing road humps in campus, whether it is effective and reliable or does it cause any discomfort. The recommendation and suggestion on how to improve the roadways in UTP are also inquired.

Sample of the questionnaires is attached in the Appendix.

3.5 Equipment Used

The following equipment involved in the study is:

i. Radar Gun
ii. Digital camera
iii. Stopwatch
iv. Measuring Tape
v. Safety Vest

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Qualitative Analysis: Questionnaires

Questionnaires were distributed to the community within the campus of UTP. There are 200 respondents that participated in the survey.

Q1: What kind of transport you have in UTP?

The results from question 1 are illustrated in Figure 14 and 15.

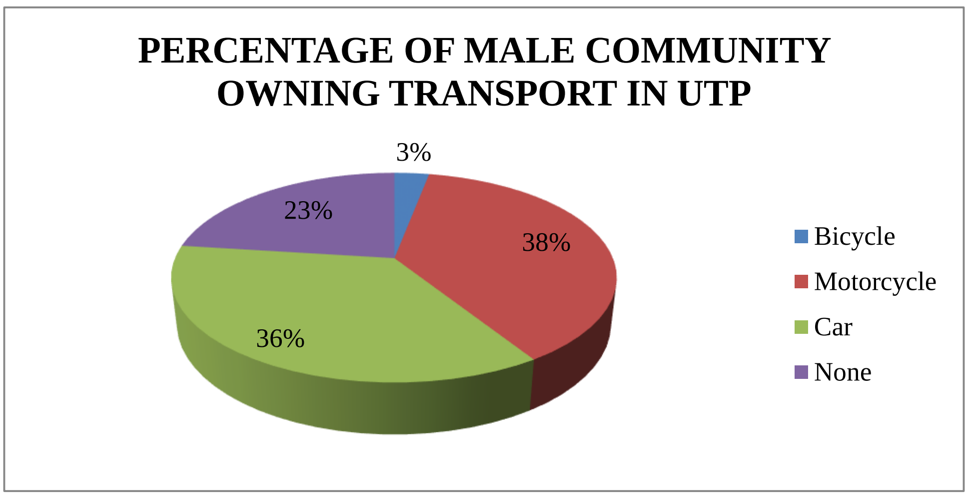

FIGURE 14: Percentage of Male Community Owning Transport in UTP

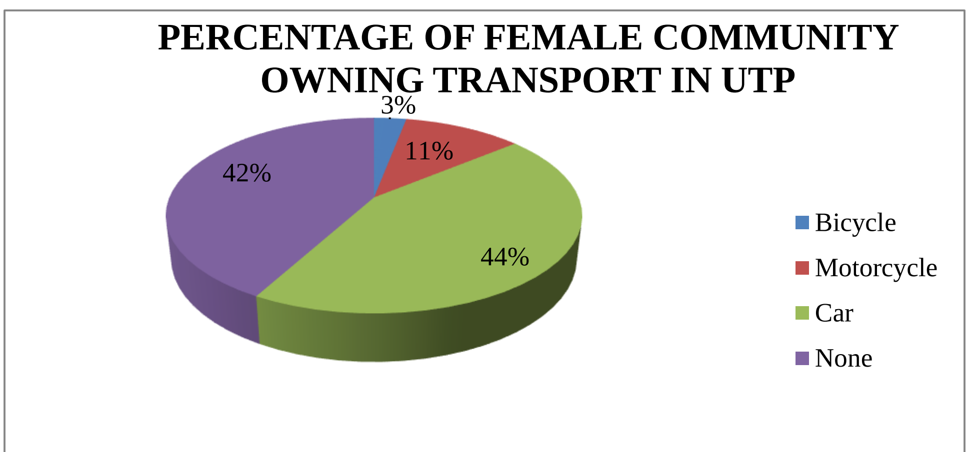

FIGURE 15: Percentage of Female Community Owning Transport in UTP

Based on the results, it shows that more number of male respondents have transport in UTP compared to female. The majority of road users from male are motorcycle users.

Q2: Are you aware of the speed limit of 40km/h in UTP?

Q3: Do you ensure yourself to always drive within the speed limit in the campus?

Based on questions 2 and 3, the results obtained are illustrated as Figure 16.

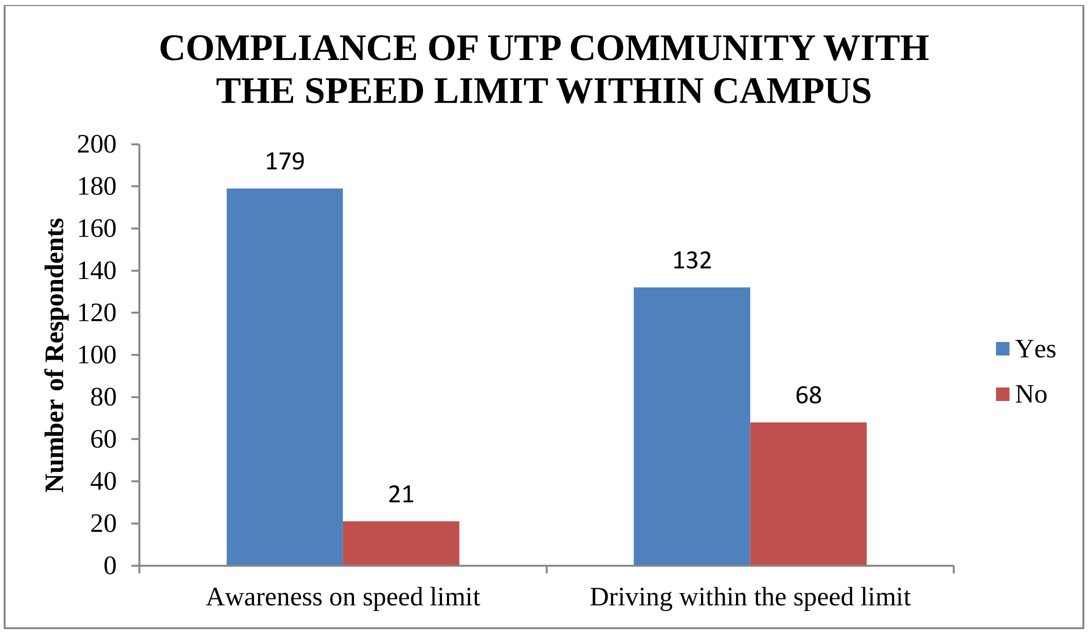

FIGURE 16: Chart of Compliance of UTP Community with the Speed Limit

From 200 respondents, it was found that 179 respondents are aware of the speed limit of 40km/h in the campus, while 21 respondents are not aware of the speed limit. Most of them are new students who do not have transport in the campus.

68 respondents admit that they do not comply with the speed limit within the campus, while another 132 respondents obey the speed limit.

Q4: Is the amount of speed humps in UTP adequate?

Result from question 4 is illustrated in Figure 17.

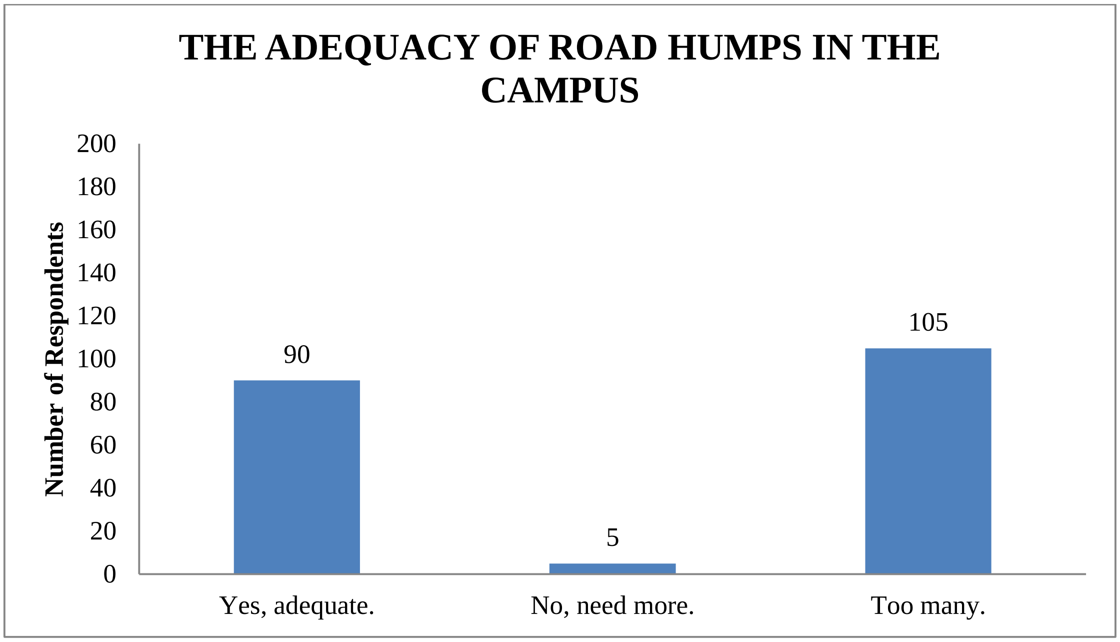

FIGURE 17: The Adequacy of Road Humps in the Campus

Based on questions 4, 105 respondents think that the number of road humps in UTP is too many. 90 respondents agree that the number of road humps in the campus is adequate while 5 more respondents feel that it is not adequate and there is a need to add more number of road humps. Hence, it shows that to some extent, road hump causes discomfort to the road users.

Q5: In your opinion, do the road humps helps in reducing vehicles speed in the campus?

Q6: Have you ever involved in an accident involving road humps in the campus?

Q7: If there were no road humps, do you think the student will drive within the speed limit within the campus?

The results from questions 5, 6 and 7 are illustrated in Figure 18.

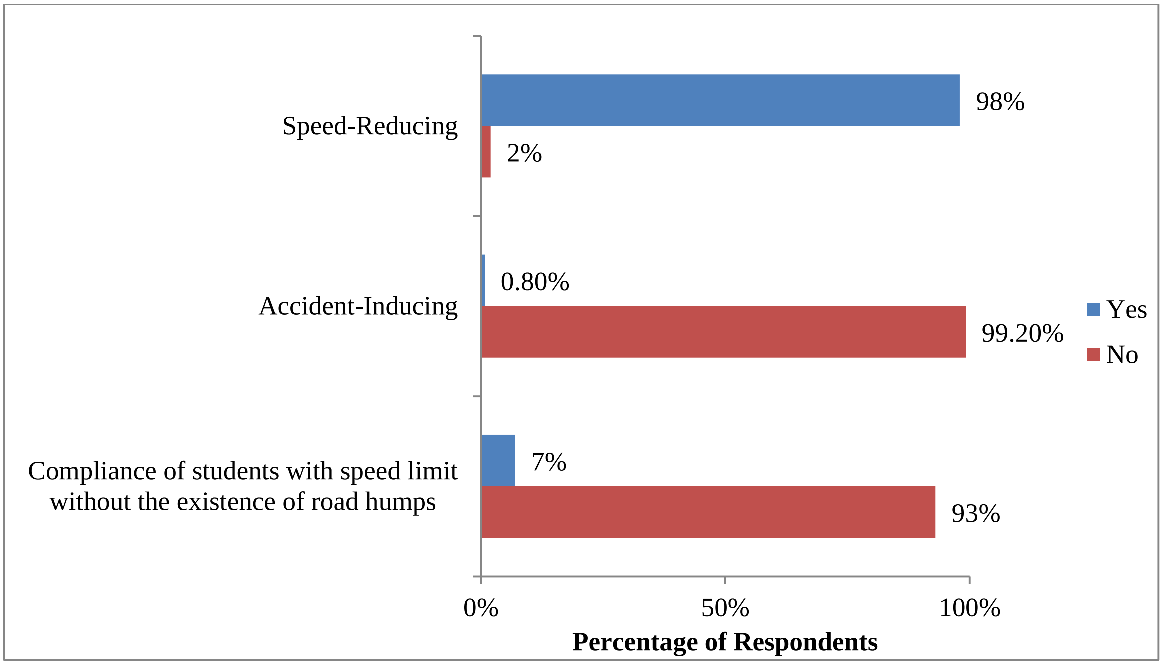

FIGURE 18: The Effectiveness of Road Humps in UTP

Based on the Figure 18, it was found that 98% respondents agree that road humps are effective in reducing vehicles speed in the campus, while the other 2% respondents disagree. 0.8% respondents stated that they have involved in accident involving road humps in the campus, while the other 99.2% respondents have not experienced accidents involving road humps in UTP. 93% respondents admit that they would not comply with the speed limit without the existence of road humps, while the rest of 7% respondents would still follow the speed limitation of 40km/h within the campus. Hence, the results show that even though road hump causes discomfort, it is a necessity to have to ensure that people are driving in the safe driving speed.

4.2 Quantitative Analysis: Spot Speed Study

For this study, 100 samples are taken at each location. This is because according to Garber (2010), the sample size needs to be at least 30 vehicles to obtain the correct data of speed of a location.

For 3 locations with road humps, the speed of each vehicle is taken at three locations: 60 meters prior to road hump, on road hump, and 60 meters after road hump. Most vehicles slow down their speed about 50 to 25 meters approaching road humps, reach their lowest speed while travelling on the road humps, and pick up their speed after passing road humps. (*Research Journal of Applied Sciences, Engineering and Technology 7(13): 2741-2746, 2014*). Engineers (2001) recommended in their research paper that for the speed limit of 40 km/h, the appropriate distance between measures is 50 km to 100 km. Hence, the distance between measures used in this study is 60 meters.

Based on the spot speed study, the average speed, median speed, modal speed, and 85^{th} percentile speed is obtained.

Average Speed is the arithmetic mean of all observed vehicle speeds (which is the sum of all spot speeds divided by the number of recorded speeds)

Median Speed is the speed at the middle value in a series of spot speeds that are arranged in ascending order. 50 percent of the speed values will be greater than the median; 50 percent will be less than the median.

Modal Speed is the seed value that occurs most frequently in a sample of spot speeds.

85^{th} Percentile Speed is the speed below which 85 percent of the vehicles travel and above which 15 percent of the vehicles travel. Most engineering approach of setting the speed limit is usually based on the 85^{th} Percentile Speed.

Figure 19 shows the layout plan of UTP obtained from the Health, Safety & Environment (HSE) of UTP. From this layout plan, the locations for survey are determined.

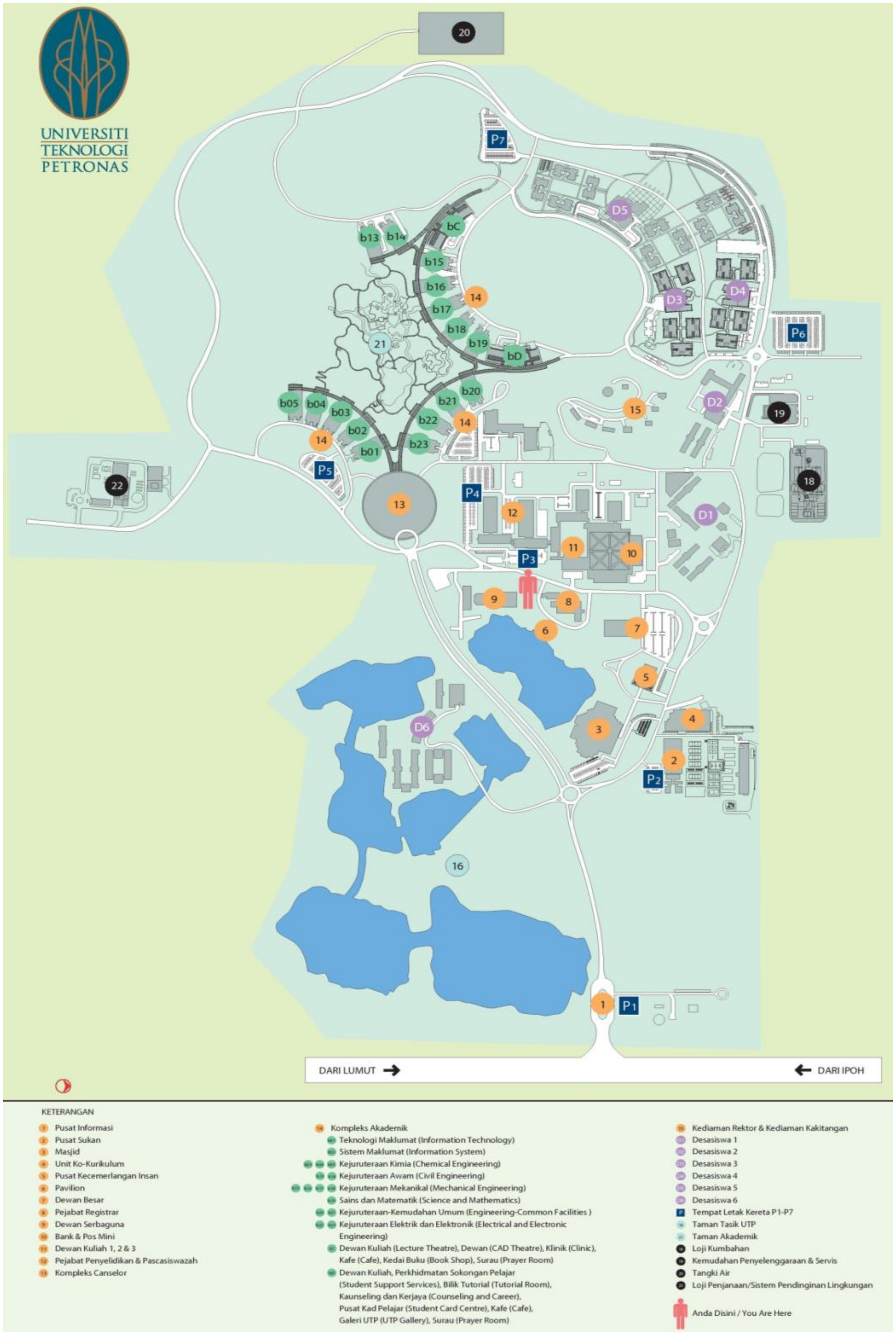

FIGURE 19: Layout Plan of UTP

Location 1: Road Hump (In Front of Village 2 Cafe)

FIGURE 20: Location 1

Figure 20 shows Location 1 which is in front of Village 2 cafe. The dimension of road hump at the location is depicted in Table 6.

Table 6: Characteristics of Road Hump at Location 1

Type	Width	Height
Round-Top	3.3 meters	5.5 centimeters

Tables 7, 8 and 9 depicted the frequency distribution table for set of speed data for (1) 60 meters approaching road hump, (2) on road hump, and (3) 60 meters after road hump, respectively.

Table 7: Frequency Distribution Table for Set of Speed Data 60 Meters Approaching Road Hump

SPEED CLASS (KM/H)	**CLASS MIDVALUE, u_i**	**CLASS FREQUENCY, f_i**	$f_i u_i$	**PERCENTAGE OF CLASS FREQUENCY**	**CUMULATIVE PERCENTAGE OF CLASS FREQUENCY**
10-14	12	0	0	0	0
15-19	17	5	85	5	5
20-24	22	5	110	5	10
25-29	27	10	270	10	20
30-34	32	22	704	22	42
35-39	37	40	1480	40	82
40-44	42	17	714	17	99
45-49	47	1	47	1	100
50-54	52	0	0	0	100
55-59	57	0	0	0	100
		100	**3410**		

Table 8: Frequency Distribution Table for Set of Speed Data on Road Hump

SPEED CLASS (KM/H)	**CLASS MIDVALUE, u_i**	**CLASS FREQUENCY, f_i**	$f_i u_i$	**PERCENTAGE OF CLASS FREQUENCY**	**CUMULATIVE PERCENTAGE OF CLASS FREQUENCY**
10-14	12	6	72	6	6
15-19	17	19	323	19	25
20-24	22	37	814	37	62
25-29	27	23	621	23	85
30-34	32	9	288	9	94
35-39	37	6	222	6	100
40-44	42	0	0	0	100
45-49	47	0	0	0	100
50-54	52	0	0	0	100
55-59	57	0	0	0	100
		100	**2340**		

Table 9: Frequency Distribution Table for Set of Speed Data 60 Meters after Road Hump

SPEED CLASS (KM/H)	CLASS MIDVALUE, u_i	CLASS FREQUENCY, f_i	$f_i u_i$	PERCENTAGE OF CLASS FREQUENCY	CUMULATIVE PERCENTAGE OF CLASS FREQUENCY
10-14	12	1	12	1	1
15-19	17	6	102	6	7
20-24	22	23	506	23	30
25-29	27	34	918	34	64
30-34	32	25	800	25	89
35-39	37	10	370	10	99
40-44	42	1	42	1	100
45-49	47	0	0	0	100
50-54	52	0	0	0	100
55-59	57	0	0	0	100
		100	**2750**		

Based on these data, the graphs of Frequency Distribution and Cumulative Distribution are plotted as Figure 21 and Figure 22, respectively.

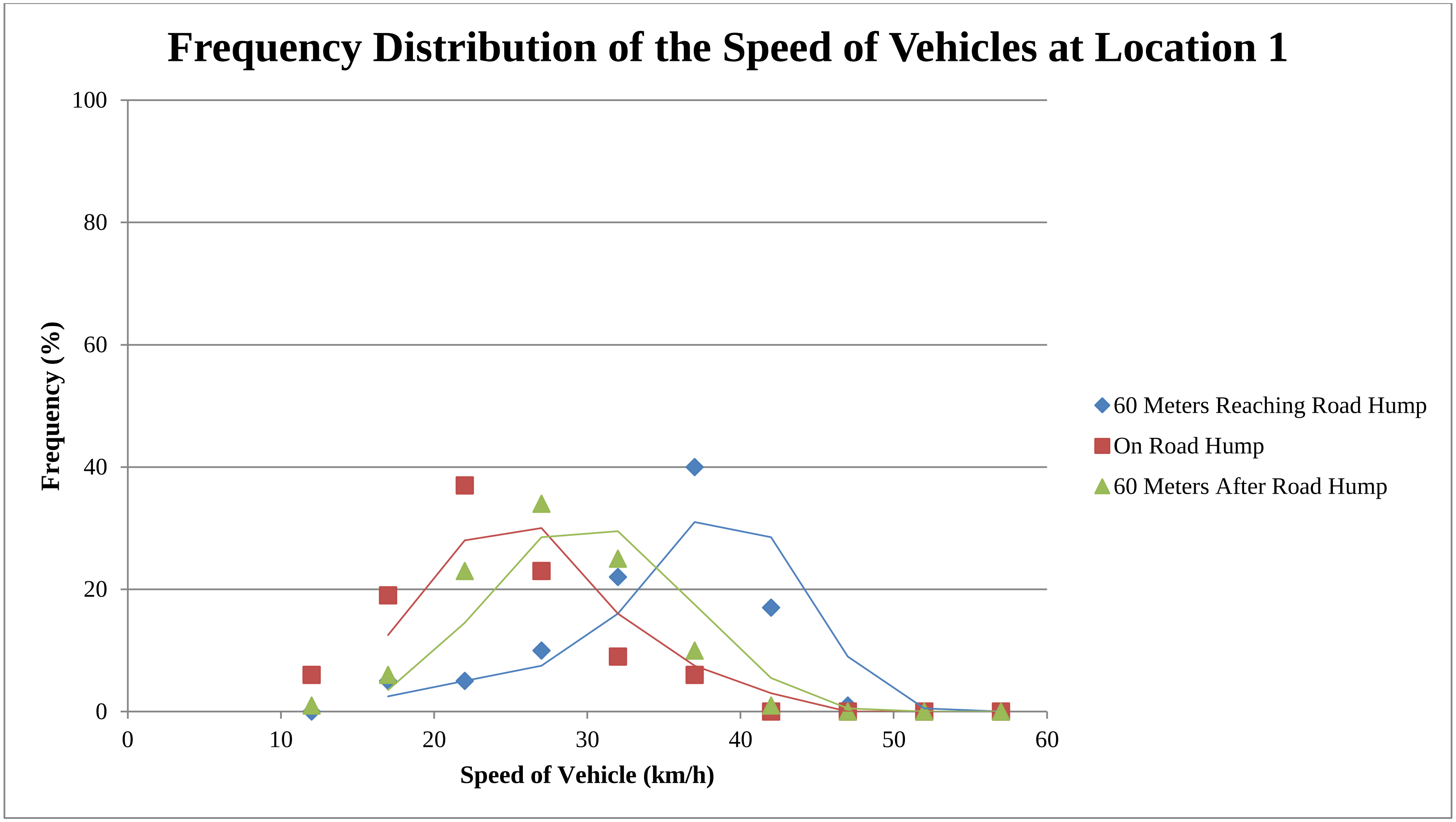

FIGURE 21: Frequency Distribution of the Speed of Vehicles at Location 1

Modal speed is obtained from this graph as the speed corresponding to the highest point on the curve is taken as an estimate of the modal speed.

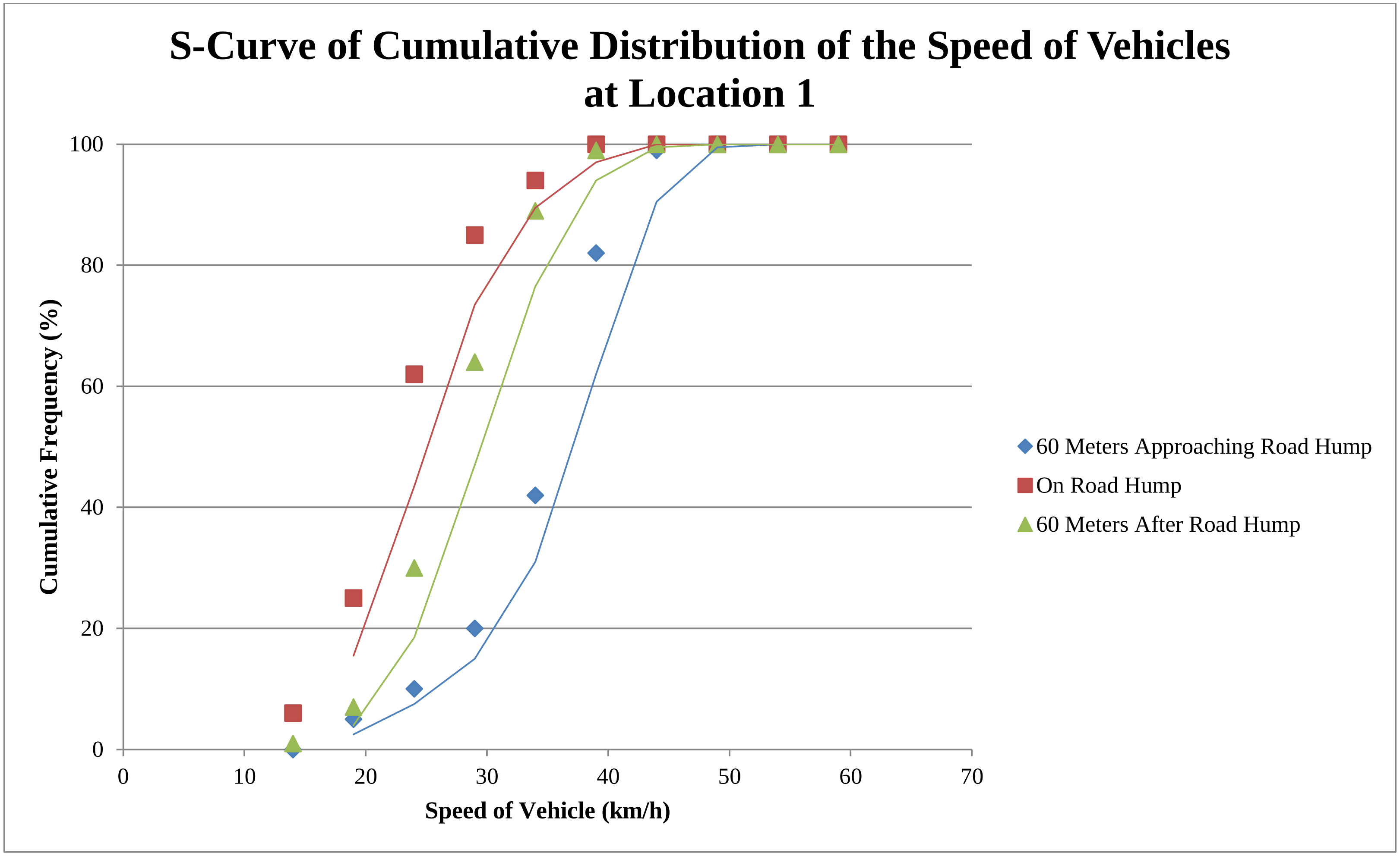

FIGURE 22: S-Curve of Cumulative Distribution of the Speed of Vehicles at Location 1

From this graph, Median Speed (the 50th Percentile Speed) and 85th Percentile Speed are obtained.

The results from the survey at location 1 are tabulated in Table 10.

Table 10: The Speed of Vehicles at Location 1

	Average Speed	**Modal Speed**	**Median Speed**	**85th Percentile Speed**
60 Meters Approaching Road Hump	34.1	37	37	43
On Road Hump	23.4	27	25.1	32.6
60 Meters After Road Hump	27.5	32	29.6	36.4

The findings showed that the average speed of vehicles travelling through the road hump at location 1 is lower than the posted speed limit in the campus which is 40 km/h. While for the 85th percentile speed, the speed of vehicles 60 meters approaching the road hump is 43 km/h, which is over the speed limit. The percentage of vehicles which travel more than 40 km/h before approaching road hump is 18% from the total sample size of 100 vehicles.

Based on Figure 20 that showed the location 1, the condition of rumble strips at the location is worn out. This might be due to inconsistent maintenance of the road. Hence, it is recommended to mend the existing rumble strips. This action will help to reduce the 85th percentile speed of vehicles in Location 1.

The steps to analyze the speed of vehicles at location 1 are repeated for all remaining five locations.

Location 2: Road Hump (From Chancellor Complex to UTP Mosque)

Figure 23: Location 2

Figure 23 shows the flat-top road hump at Location 2 which is at the road from Chancellor Complex to UTP mosque. Table 11 described the dimension of road hump at the location.

Table 11: Characteristics of Road Hump at Location 2

Type	Width	Height
Flat-Top	5.36 meters	6.2 centimeters

The results from the survey at location 2 are tabulated in Table 12.

Table 12: The Speed of Vehicles at Location 2

	Average Speed	**Modal Speed**	**Median Speed**	**85th Percentile Speed**
60 Meters Approaching Road Hump	38.35	42	40.7	47
On Road Hump	24.45	22	25.7	34.2
60 Meters After Road Hump	33.05	30	34.8	41.4

Averagely, the speed of vehicles at location 2 is according to the posted set limit. However, the 85th percentile speed shows violation of speed for both vehicles approaching the road hump and leaving the road hump. They only slow down while passing on the road hump. About 45% of vehicles from the sample size travel over speed limit approaching the road hump, and only 11% travel over 40 km/h leaving the road hump.

Figure 23 shows that there were no rumble strips installed on the road leading to the road hump. The drivers on the road are not forced to slow down as they perceived it to be safe to be travelled with a higher speed. Hence, most vehicles travelling in location 2 tend to drive with a high speed over the speed limit.

To mitigate this, the installation of rumble strips is recommended at location 2. It is expected to reduce the rate of accident and specifically to reduce the crash rate occur due to drivers' inattentiveness (Transportation Research Engineer, 2008).

Location 3: Road Hump (Before Junction to Gate 3)

Figure 24: Location 3

Figure 24 shows Location 3 which is at the road before junction to Gate 3 of UTP. The dimension of road hump at the location is depicted in Table 13.

Table 13: Characteristics of Road Hump at Location 3

Type	Width	Height
Round-Top	1.7 meters	6.0 centimeters

The results from the survey at location 3 are tabulated in Table 14.

Table 14: The Speed of Vehicles at Location 3

	Average Speed	**Modal Speed**	**Median Speed**	**85^{th} Percentile Speed**
60 Meters Approaching Road Hump	32.7	32	33.6	45.4
On Road Hump	18.5	22	20	27
60 Meters After Road Hump	28.65	32	30.4	38.2

Based on the results, there is a wide variation of speed of vehicles before approaching the road hump, on the hump and after leaving the hump at location 3. The average speed of vehicles at location 3 is lower than the posted speed limit of 40 km/h. For the 85^{th} percentile speed, the speed of vehicles approaching the road hump recorded a speed of 45.4 km/h. 22% of vehicles is documented to travel with the speed of above 40 km/h while approaching the road hump.

This might be due to low volume of traffic passing through access road at location 3 as it is not the main road. Most of road users in UTP tend to use the access way to the main gate. Hence, drivers feel that it is safe to drive in a higher speed at this location compared to other main roads.

Location 3 also shows almost the same outcome as Location 1. Based on Figure 24, it shows that the condition of the existing rumble strip at Location 3 too is worn out and need to be reconstructed. By rehabilitating the existing rumble strips at this location, it will help to reduce the 85^{th} percentile speed of vehicles passing through this road.

Location 4: Road Behind Block 1 and Block 2 (No Road Hump)

Figure 25: Location 4

Figure 25 shows Location 4 which is at the road behind Block 1 and Block 2. The results from the spot speed survey are tabulated in Table 15.

Table 15: The Speed of Vehicles at Location 4

Average Speed	Modal Speed	Median Speed	85th Percentile Speed
44.55	52	47.2	57

Based on Table 15, it was found that both the average speed and 85^{th} percentile speed of vehicles at location 4 recorded a very high speed which exceeds the speed limit in the campus. 72% of vehicles from the sample size drive with speed of more than 40 km/h at the location.

The high speed of vehicles is due to the big gap of interval between road humps at location 4. Hence, drivers tend to speed at the interval.

Hence as a mitigation step, it is recommended to install road hump and rumble strips at this road. Based on the research by U.S. Department of Transportation, the combination measures of road hump and rumble strips will result in a 33% reduction of 85^{th} percentile speed of vehicles after the installation.

However, there are some guidelines to be fulfilled before the installation. According to the specification by Ministry of Highway Planning Unit, the appropriate distance between road hump should be between 60 meters and 230 meters. Hence, the fulfillment of the requirement has to be checked first before it is being placed.

Location 5: The Road beside Village 4 Soccer Field (No Road Hump)

Figure 26: Location 5

Figure 26 shows Location 5 which is at the road beside Village 4 soccer field. The results from the spot speed survey are tabulated in Table 16.

Table 16: The Speed of Vehicles at Location 5

Average Speed	**Modal Speed**	**Median Speed**	**85^{th} Percentile Speed**
44.55	47.1	46.5	56

Both the average speed and 85^{th} percentile speed of vehicles at location 5 recorded a very high speed which exceeds the speed limit in the campus. 70% of vehicles from the sample size drive with speed of more than 40 km/h at the location.

This location is the main access road to academic block which is Pocket C. The drivers' speeding behavior is most likely due to reach to their class early. The same approach recommended at location 4 can be used to mitigate the speeding in location 5 as the speed profiles at both locations are similar.

Location 6: The Road from Gate 3 to Pocket C (No Road Hump)

Figure 27: Location 6

Figure 27 shows Location 6 which is at the road from Gate 3 to Pocket C. The results from the spot speed survey are tabulated in Table 17.

Table 17: The Speed of Vehicles at Location 6

Average Speed	**Modal Speed**	**Median Speed**	**85th Percentile Speed**
48.7	52	51	58.5

Based on Table 17, both the average speed and 85th percentile speed of vehicles at location 6 recorded a very high speed which exceeds the speed limit in the campus. 85% of vehicles from the sample size drive with speed of more than 40 km/h at the location.

Within the three locations with no road humps, this location recorded the highest speed profiles. This might be to its distance to the nearest road humps is very far compared to other two locations. The interval between road humps is one of the most important factors in calming the speed of vehicles on the road. The speed of vehicles will be around 15-20 km/h when travelling near road humps, and the speed increases as the interval between road humps increases (Aya Kojima et al, 2011**).**

To attenuate this, it is recommended to install the combination measure of road hump and rumble strips, likewise as recommended for Location 4 and Location 5. This is because the combination of both measures promised a high reduction of vehicular speed after the installation.

CHAPTER 5

CONCLUSION AND RECOMMENDATION

5.1 Conclusion

Based on the literature review from multiple sources, road hump is the most effective measure in traffic calming as it involves vertical deflections in carriageway. It is the most effective measures in reducing vehicles speed as it introduce ‘shock’ while travelling through it. As the speed of vehicles decrease, so is the number and impact of collisions to vehicles and road users. Thus, road hump helps promote a safe environment for the road users and also the residents. Road hump is the optimum traffic calming measure as it is highest speed-minimizing device which comes with the lowest cost of $2000 in comparison with other traffic calming measures.

The findings from the literature review are verified by conducting this study on the basis of quantitative analysis and qualitative analysis. Quantitative analysis is obtained from Spot Speed Study and qualitative analysis is obtained from questionnaires. The questionnaires comprised of 9 questions (attached in Appendix) were distributed to 200 respondents of various occupations and gender within the campus of UTP. The results show that most of the respondents have transports in the campus and they are aware of the speed limit within the campus. The minority who is not aware with the speed limit of 40km/h are mostly new intake students who do not have any form of transportation within the campus. Majority of the students comply with the speed limit while driving in the campus.

98% agree that road humps help in reducing vehicles speed in the campus. However more than half of the respondents were disturbed by the excessive amount of road humps which might cause them discomfort. Although 93% admit that they would not abide by the speed limit without the existence of road humps in the campus. So this shows that road hump is a necessity to have in the campus even though it is not wanted by several students.

Spot Speed Study has been conducted at 6 locations: 3 with road humps and 3 with no road humps. The results at Location 1, 2, and 3 shows that the average speeds of vehicles on those roads are following the posted speed limit in the campus. However, the 85^{th} percentile speeds of vehicles range from 40-47km/h. This might be due to the absence or improper maintenance of the existing rumble strips. Hence it is recommended to rehabilitate the rumble strips to achieve the optimum road condition.

Results from the survey at location 4, 5, and 6 shows very high speed of vehicles at all three locations. A high percentage of vehicles at those locations exceed the posted speed limit of 40 km/h in the campus. The usage of combination measure of road humps and rumble strips is recommended to solve the issue of speeding at these locations.

The survey also proved the importance of following the specifications given by the Ministry of Highway Planning Unit, Malaysia in deciding the interval of road humps. According to Farzana Rahman et al (2007), the appropriate design of road humps resulted in vehicular speed of 23.4-31.2 km/h when travelling through the road and 39-46.8 km/h at proper distance of intervals of road humps.

From the survey, it is quite clear that road hump causes reduction in vehicular speed. This is obtained from the comparison of results at locations with road humps and with locations with no road humps. At location with no road humps, the speed of vehicles is notably higher. However, a few modifications need to be done to the existing road with road humps to improve the condition of roads in UTP.

5.2 Recommendations

This research covers the survey at six locations in the campus; three locations with the existing road humps and three locations without road humps. From those six locations, the speed profiles of vehicles in the campus are determined. However, for future works, it is recommended to conduct the survey at all road humps for a more accurate result if it is viable within the permitted time. This is to justify the characteristics and condition of every road humps in the campus and from there, the behavior of drivers in UTP can be compute.

The radar gun used in this survey is also another form of reliability. During rainy days and gloomy weather, the speed of vehicle is quite hard to be captured. The radar gun also cannot capture the speed of vehicles that are in 2 meters distance from it or that are moving too fast. This is because of the limitation of the instrument. Hence, it is recommended to upgrade to better equipment for future research.

Another form of reliability is the drivers' consciousness. Because of the presence of radar gun, drivers tend to not drive in their usual speed. Hence, the accuracy of the vehicle speed profiles can be disputed. Therefore, it is advised for future researchers to find a suitable locations consisting of a hut or any structures or bushes to take cover in order to not be seen by the drivers.

The author was given a measuring tape to measure the width of road humps. However, the tape is not accurate in determining the dimension due to human error and also physical shape of the humps. The author managed to obtain the GPS equipment from the department to complete this task.

Questionnaires were also distributed to the community in the campus. However, the results from the questionnaires were not taken as a large weightage in resolving the issue on the roads in the campus. For future works, it is recommended to take into account the opinion of road users in the decision-making to improve the condition of roads in the campus of UTP.

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APPENDIX

Questionnaire Form

SURVEY ON ROAD HUMPS IN UTP

Gender: Male / Female   Occupation: Student / Staff

This study is conducted to obtain feedback from the community of Universiti Teknologi PETRONAS regarding the effectiveness of traffic humps in the campus and to obtain suggestions to improve the current traffic condition.

1. What kind of transport you have in UTP?
    a. Bicycle
    b. Motorcycle
    c. Car
    d. None

2. Are you aware of the speed limit of 40km/h in UTP?
    a. Yes
    b. No

3. Do you ensure yourself to always drive within the speed limit in the campus?
    a. Yes
    b. No
    c. Sometimes

4. Is the amount of speed humps in UTP adequate?
    a. Yes, it is adequate.
    b. No, we need more.
    c. There is too many of it.

5. In your opinion, do the road humps helps in reducing vehicles speed in the campus?
   a. Yes.
   b. No.

6. Have you ever involved in an accident involving road humps in the campus?
   a. Yes.
   b. No.

   If yes, please state how:

   ____

   ____

7. If there were no road humps, do you think the student will drive within the speed limit within the campus?
   a. Yes.
   b. No.

8. Which location in the campus that you think is dangerous to the road users?

   ____

9. Do you have any suggestion to improve the current traffic condition in UTP?

   ____

   ____

   ____

Thank you for your cooperation.