THE EFFECT OF ROAD HUMPS AND RAISED CROSSWALKS ON VEHICLES SPEED

by

Nur Adilawati Binti Mohd Roslan

Dissertation submitted in partial fulfilment of
the requirements for the
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Universiti Teknologi PETRONAS
Bandar Seri Iskandar
31750 Tronoh
Perak Darul Ridzuan

CERTIFICATION OF APPROVAL

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Approved by,

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ASSOC. PROF. DR. MADZLAN NAPIAH
Project Supervisor

UNIVERSITI TEKNOLOGI PETRONAS
TRONOH, PERAK

December 2008

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 that the original work contained herein have not been undertaken or done by unspecified sources or persons.

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(NUR ADILAWATI BINTI MOHD ROSLAN)

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I hope that the project will not only serve for academic purposes, but will also be beneficial to the community.

ABSTRACT

At Universiti Teknologi PETRONAS, speeding is one of the most common traffic offences by the students. A few traffic calming measures such as road humps and raised crosswalks were implemented with the purpose to reduce the speeding offence in the university. However, the effectiveness of the implementation is never been studied. This project will evaluate the feasibility of these structures in detail. Data collection was the first step conducted using questionnaires to obtain feedback from the users on the effectiveness of using the existing traffic calming structures. In reconnaissance survey, locations of selected road humps and raised crosswalks were determined. In data gathering process, dimension of the existing structures were measured using recommended method to determine whether the design met the standard specifications. The most important part was determining the speed of the moving vehicles using radar gun. Series of data on speeds of the vehicles were used to construct the speed profiles. The results show that at some of the locations of the study, the traffic calming measures could not effectively reduce the speed of vehicles and exceeded the speed limit of the campus. Therefore, modifications on the design of the structures in terms of dimension are proposed to meet the design specifications. There are also recommendations to introduce other traffic calming structures that are having the potential in reducing the speed of vehicles.

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1.0 INTRODUCTION

1.1 Background of Project

Universiti Teknologi PETRONAS (UTP) was established on January 10, 1997 when PETRONAS was invited by the Malaysian government to set up a university. The university is strategically located at Bandar Seri Iskandar, Perak Darul Ridzuan, Malaysia. The university is a wholly-owned subsidiary of PETRONAS, the national oil company of Malaysia. UTP offers a wide range of engineering and technology programmes at undergraduate and postgraduate levels complemented with a strong focus on Research and Development. The programmes are designed with high industry relevance to provide a dynamic learning environment to fulfil the university vision in becoming leader in technology education and centre for creativity and innovation. The objective of the university is to produce well-rounded graduates who are creative and innovative with the potential to become leaders of industry and the nation. *(Universiti Teknologi PETRONAS, 2008)*

One of the ways to achieve the objective of the university is by providing a comfortable, yet safe learning environment. This includes providing a safe condition for the students to travel around the campus. The management of the university had decided to implement several traffic calming measures around the campus.

Traffic calming is defined as the combination of mainly physical measures that can reduce the negative effects of motor vehicle use, amend driver driving behaviour and improve safety for non-motorised road users. It is fundamentally concerned with reducing the adverse impact of motor vehicles on built up areas. This usually involves reducing vehicle speed and volume, providing more space for pedestrians and cyclists, and improving traffic safety and the local environment. *(Jurutera Perunding Zaaba Sdn. Bhd., 2000)*

1.2 Problem Statement

At Universiti Teknologi PETRONAS, speeding and excessive number of vehicles are two of the most common problems believed to be caused by students themselves.

Increase in students' financial income has drastically increased the number of vehicles on the roads. However, this problem has been controlled through law enforcement by the management of the university. Nevertheless, when in a hurry to get to class or home, students often ignore speed limits around the campus. The result of these phenomena is an increasing concern from the students, staffs and visitors on safety considerations.

Realizing this situation, the management had decided to implement speed control measures which are speed humps, raised crosswalks and rumble strips. These structures are physical measures which use forces of vertical acceleration to reduce speed of the vehicles.

1.3 Objective

The implementation of several speed control measures are said to have successfully reduced speeding problem in the university. Thus, the objectives of the project are as follows:

- To evaluate the *effectiveness of the existing* road humps and raised crosswalks as speed control measures
- To *recommend the optimum dimension and design* of the respective structures.

1.4 Scope of Study

The study of the project shall involve several scopes as explained below:

i. Questionnaires

- Questionnaires are distributed to obtain feedback from the students and staffs on effectiveness of existing traffic calming measures. The questionnaires are also expected to include the respondents' opinions and suggestions for improvement of current traffic calming measures.

ii. Reconnaissance Survey

- Reconnaissance survey is conducted to obtain dimension of the existing traffic calming structures and will be determined whether the design met the specifications outlined by the Highway Planning Unit (HPU), Ministry of Works Malaysia.

iii. Spot Speed Study

- Speed of moving vehicles are determined using radar gun or/and video capturing. A series of data on the vehicles speed at different locations are used to construct the speed profiles for specific humps. The results are used to:
  - Determine the average maximum speed reached at a certain location of the study.
  - Obtain the optimum spacing between consecutive humps to achieve the intended speed limit.

CHAPTER 2

2.0 LITERATURE REVIEW

2.1 Needs of Traffic Calming Measures

Traffic calming is the combination of mainly physical measures that reduce the negative effects of motor vehicle use, alter driver behaviour and improve conditions for non-motorised road users.

Traffic calming is a method to reduce the adverse impact of motor vehicles on built up areas. This usually involves reducing vehicle speed and volume, providing more space for pedestrians and cyclists, and improving traffic safety and the local environment.

The objectives of traffic calming include:

- to improve the environmental quality of roads;
- to improve safety and reduce accidents;
- to reduce noise, disturbance and anxiety;
- restoration of communities divided by speeding traffic;
- to enhance of the appearance of streets;
- discouragement of the use of unsuitable route by heavy vehicles and through traffic;
- to change the attitude of many drivers toward speed; and
- to demonstrate the function of the streets for people as well as for traffic.

Traffic calming measures are necessary at areas where traffic related problems occurred such as;

- High volume through traffic – determined from traffic counts.
- Speeding – determined from speed measurement.

- Traffic accidents – determined from observations or historical data. *(Jurutera Perunding Zaaba Sdn. Bhd., 2000)*

2.2 Traffic Calming Measures Techniques

Traffic calming schemes generally include a wide range of measures designed to complement each other in both speed reduction and environmental terms. The effectiveness of this varies according to the measures employed. The principle techniques used fall into two areas:

- Through traffic control measures.
- Speed control measures.

2.2.1 Through traffic control measures

2.2.1.1 Full road closures (cul-de-sacs or dead ends).

- Barriers are placed across a road to close it completely to through traffic, usually leaving only sidewalks and cycle paths open. The barriers may consist of landscaped islands, walls, gates, side-by-side bollards, or any other obstructions that leave any opening smaller than the width of a passenger car. Figure 1 shows layout and picture of full road closures.

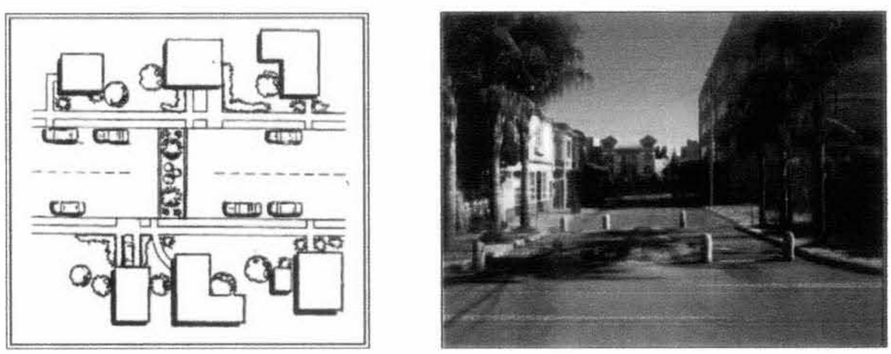

Figure 1: Full Road Closure *(Jurutera Perunding Zaaba Sdn. Bhd., 2000)*

2.2.1.2 Partial road closures.

- Partial closures as shown in Figure 2 are barriers that block travel in one direction for a short distance on otherwise two-way roads. When two partial closures are placed across from one another at an intersection, the result is a semi-diverter.

- Half closures in Figure 3 are sometimes located internal to blocks between residential and non residential land uses. The main advantage of placing them there is to buffer residences from business traffic.

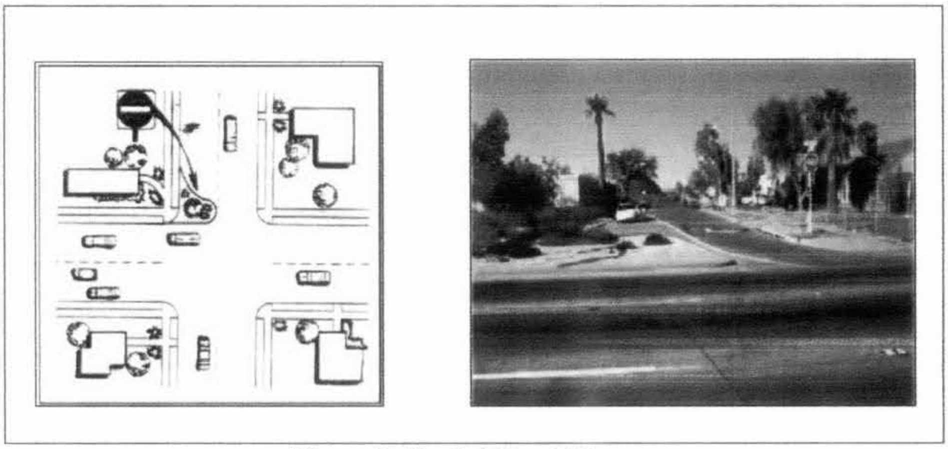

Figure 2: Partial Road Closure
(Jurutera Perunding Zaaba Sdn. Bhd., 2000)

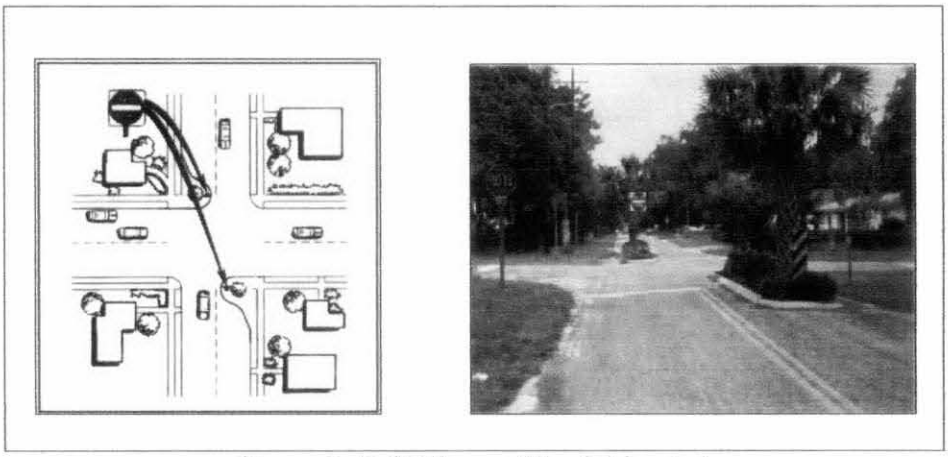

Figure 3: Half Closure (Semi-Diverter)
(Jurutera Perunding Zaaba Sdn. Bhd., 2000)

2.2.2 Speed traffic control measures

- There are three types of speed control measures which are:

- **Vertical measures**; which use forces of vertical acceleration to discourage speeding.
- **Horizontal measures**, which use forces of lateral acceleration to discourage speeding.
- **Road narrowing** and **central islands**, which use a psycho-perceptive sense of enclosure to discourage speeding.

2.2.2.1 Vertical deflections

- Vertical shifts in the carriageway are the most effective and reliable of the speed reduction measures currently available. There are currently several different techniques available to achieve this:

a) Road hump

In Figure 4, road humps are raised areas placed across the road and may be of several varieties, with rounded and flat topped being the most common. The flat topped are particularly suitable in providing crossing places for pedestrians.

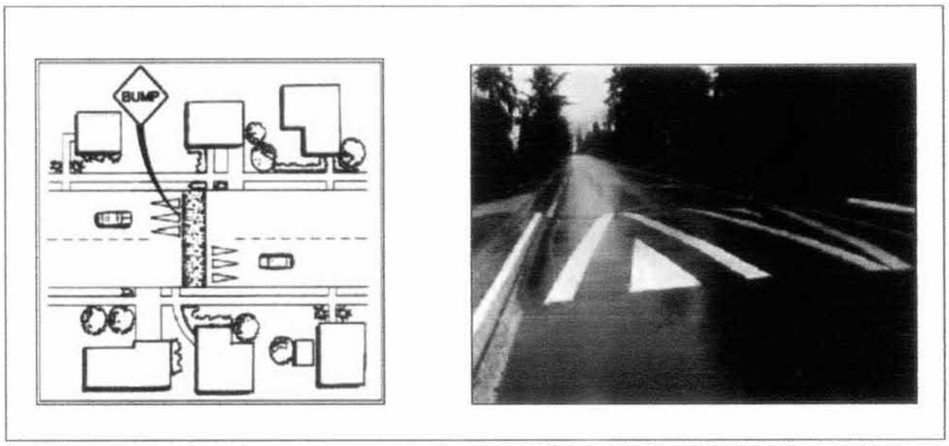

Figure 4: Road Hump *(Jurutera Perunding Zaaba Sdn. Bhd., 2000)*

b) Raised Crosswalks

Figure 5 shows raised crosswalks which are essentially broad, flat-topped speed humps that coincide with pedestrian crosswalks at street intersections. The crosswalks are raised above the level of the roadway to slow traffic, enhance crosswalk visibility, and make the crossing easier for pedestrians who may have difficulty stepping up and down curbs.

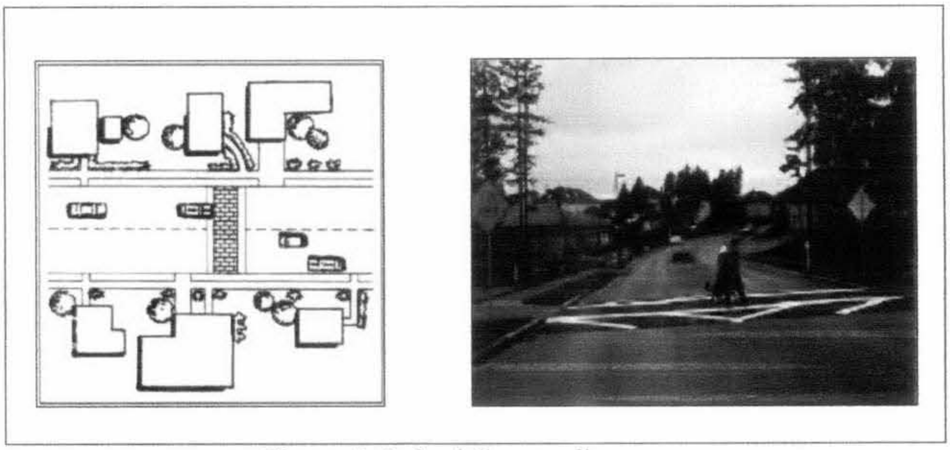

Figure 5: Raised Crosswalk
(Jurutera Perunding Zaaba Sdn. Bhd., 2000)

c) Speed cushion

Speed cushions as shown in Figure 6 are raised portions of carriageway with a flat top only extending over part of the carriageway width. Vehicles with double-rear wheels are affected by the cushions. However, cyclists and large vehicles such as buses will pass unhindered.

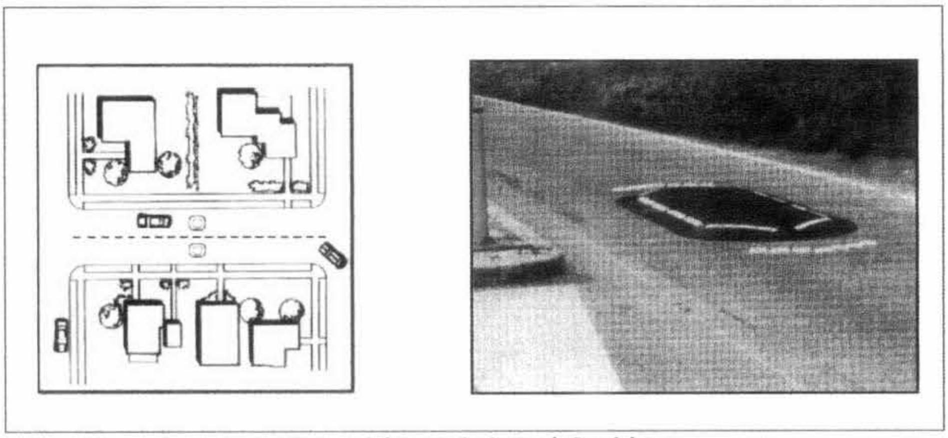

Figure 6: Speed Cushion
(Jurutera Perunding Zaaba Sdn. Bhd., 2000)

d) Textured pavements

Textured pavements are roadway surfaces paved with brick, concrete pavers, stamped asphalt, cobblestone or other surface materials that produce constant small changes in vertical alignment. Apart from being appealing and aesthetic, cobblestone and brick streets will present difficulties for pedestrians and bicycles, particularly in wet conditions as displayed in Figure 7.

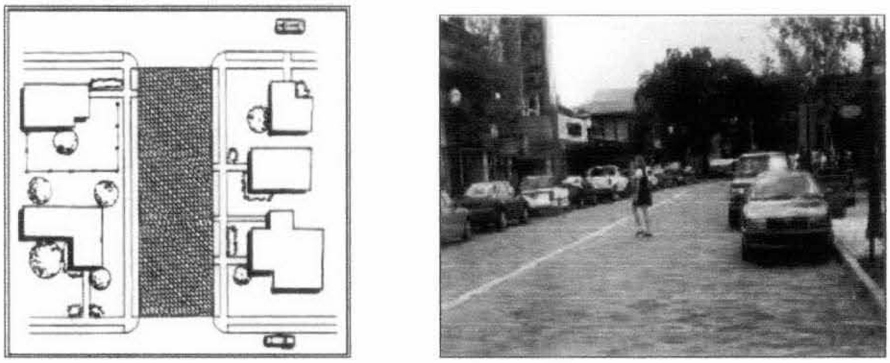

Figure 7: Textured Pavement
(Jurutera Perunding Zaaba Sdn. Bhd., 2000)

2.2.2.2 Horizontal deflections and central islands

- Horizontal measures reduce speed by forcing drivers around horizontal curves and by blocking long views of the road ahead. The most common horizontal measures are;

a) Mini-roundabouts

Mini-roundabouts as in Figure 8, are sometimes called intersection islands and are placed in intersections, around which traffic circulates. They are usually circular in shape and landscaped in their centre islands and are typically controlled by Give-way signs on all approaches.

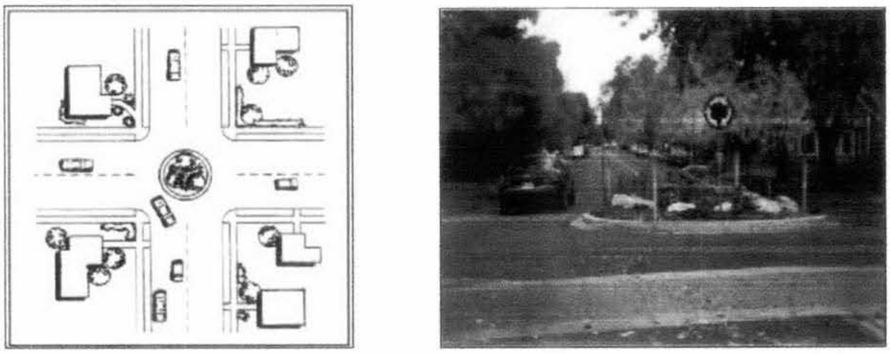

Figure 8: Mini Roundabout *(Jurutera Perunding Zaaba Sdn. Bhd., 2000)*

b) Chicanes

Chicanes are kerb extensions that alternate from one side of the street to the other, forming S-shaped curves. Chicanes may still permit speeding by drivers cutting straight paths across the centre line or testing their skills on the curves. Thus, it is recommend shifts in alignment of at least one lane width, deflection angles of at least 45 degrees, and centre islands to prevent drivers from taking a straight "racing line" through the chicane as illustrated in Figure 9.

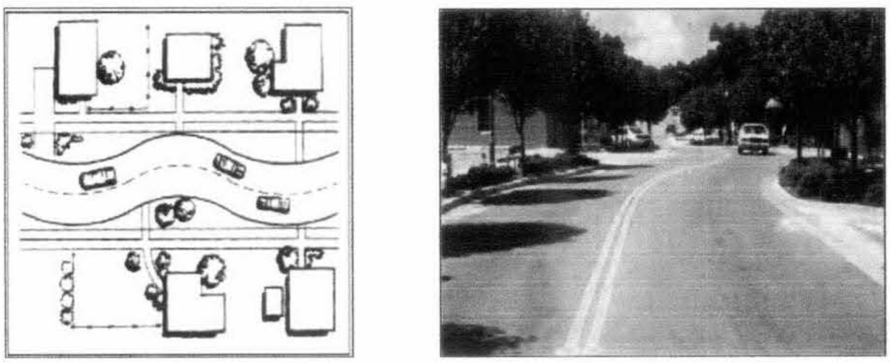

Figure 9: Chicane *(Jurutera Perunding Zaaba Sdn. Bhd., 2000)*

c) Modified intersections

Modified intersections in Figure 10 are changes in alignment that convert T-intersections with straight approaches into curving streets that meet at right angles. A former "straight-through" movement along the top of the T becomes a turning movement. Realigned intersections are sometimes called modified intersections.

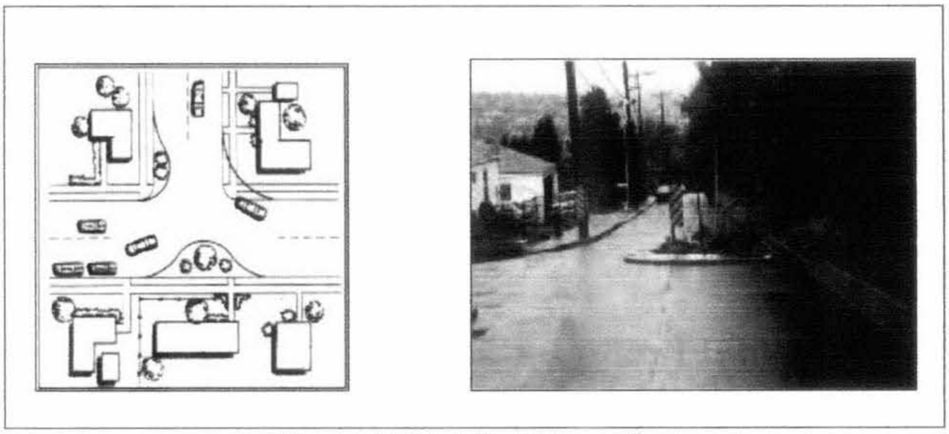

Figure 10: Modified Intersection
(Jurutera Perunding Zaaba Sdn. Bhd., 2000)

- Horizontal shifts in the carriageway are less effective than vertical ones in achieving reductions in speed. However their impact is significantly increased when used in combination with a vertical shift. In actual fact, all horizontal shifts may be classified as chicanes.

2.2.2.3 Road Narrowing

- Road narrowing may be considered as another supportive measure to vertical deflections. It cannot be considered as a speed reducing device in itself, but it can act as a reminder or encouragement to drive slowly or calmly.

- Narrowing the carriageway at specific locations, for example in combination with speed tables, is an effective way of combining measures to increase their effect. If the carriageway width is reduced to a single lane by the narrowing, the effectiveness of this technique in speed reduction is further increased.

- The types of road narrowings are:
  a) Bulbouts or intersection narrowings

  In Figure 11, Bulbouts are kerb extensions at intersections that reduce roadway width kerb to kerb. If coupled with crosswalks, they are referred to as safe crosses. Bulbouts are the most common type of street narrowing.

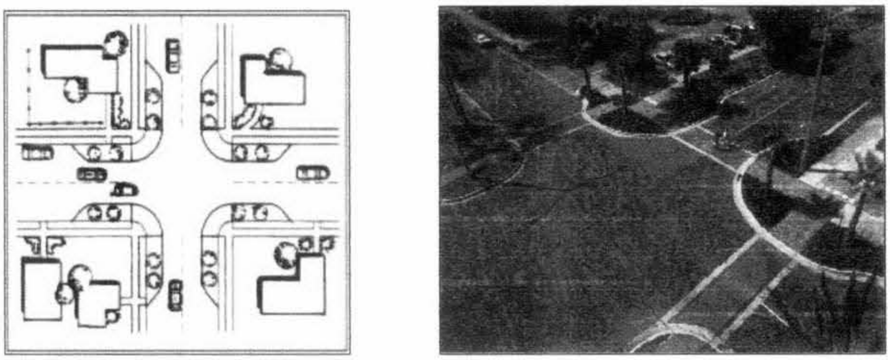

Figure 11: Bulbouts *(Jurutera Perunding Zaaba Sdn. Bhd., 2000)*

  b) Centre islands

  Centre island as shown in Figure 12 are raised islands located along the centreline of a street that narrow the travel lanes at that location. They often are nicely landscaped to provide visual amenity and neighbourhood identity. They are often called gateways if it is placed at the entrance to a neighbourhood, and often combined with textured pavement and monument signs. Centre islands have been used effectively on curves to reduce speeding.

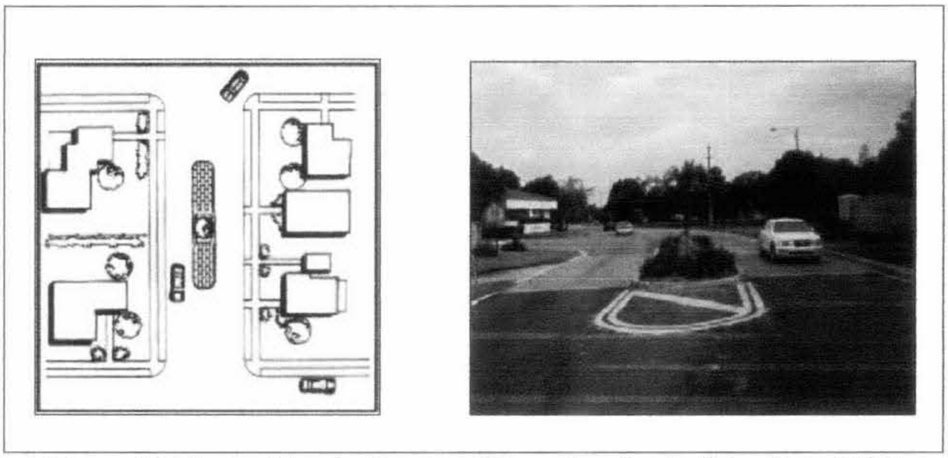

Figure 12: Centre Islands *(Jurutera Perunding Zaaba Sdn. Bhd., 2000)*

c) Chokers

Chokers in Figure 13 are curb extensions at midblock that narrow a street by widening the sidewalk or planting strip. If marked as crosswalks, they are also called safe crosses.

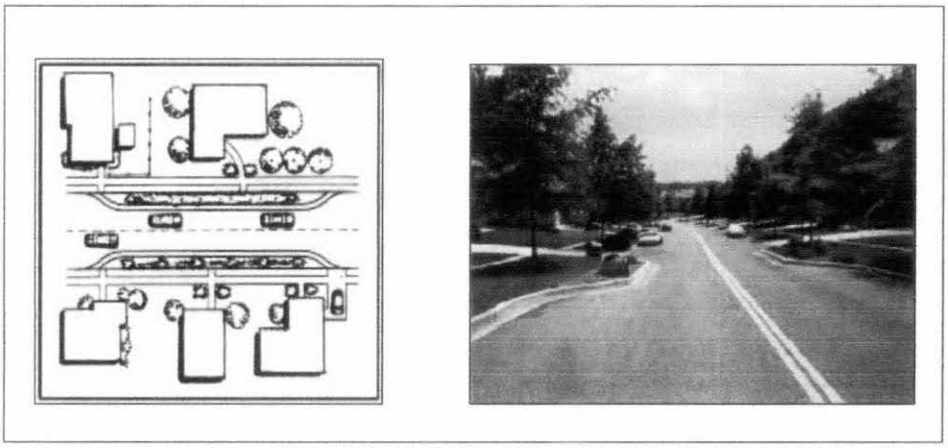

Figure 13: Chokers *(Jurutera Perunding Zaaba Sdn. Bhd., 2000)*

2.3 Road Humps

K W Tam (2006) explains that there are four types of road humps which are circular, sinusoidal, parabolic and flat-topped. The most commonly used are round-topped and flat-topped. The flat-topped or plateau hump is easiest to construct and maintain and was later used as pedestrian crossing. The dimension of road humps based on HPU is given in Table 1:

Table 1: Dimension Specifications of Road Humps

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

(Highway Planning Unit, Ministry of Works Malaysia, 2000)

The profiles of flat-top hump and round-top hump are as shown in Figure 14 and Figure 15.

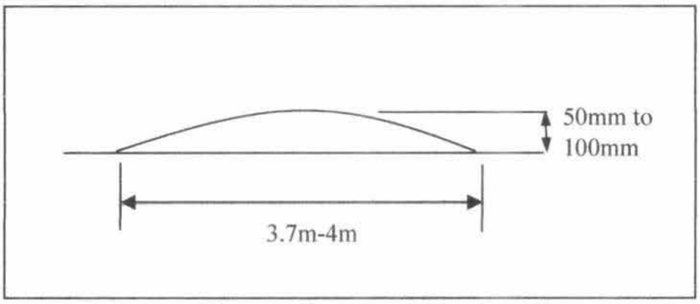

Figure 14: Round-Top Profile
(Highway Planning Unit, Ministry of Works Malaysia, 2000)

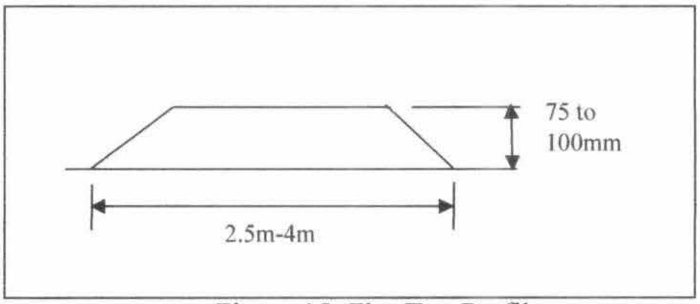

Figure 15: Flat-Top Profile
(Highway Planning Unit, Ministry of Works Malaysia, 2000)

The road humps are chosen because it is low in cost and their effectiveness in reducing vehicle operating speed; typically by 10 to 20 kph if properly spaced. However, they are rated worst for appearance, liability and rough ride especially after being used for a period of time. This can be improved with landscaped street edges and moderate marking and signage. With coloured and stamped asphalt, humps may even improve on the appearance of uninterrupted asphalt. *(Jurutera Perunding Zaaba Sdn. Bhd., 2000).*

Some of the road humps that have been implemented in overseas are as shown in Figure 16 (Korea) and Figure 17 (Lancashire). Table 2 explains the advantages and disadvantages of road hump.

Figure 16: Road Hump in Korea

Figure 17: Road Hump in Lancashire

Table 2: Advantages and Disadvantages of Road Hump

Advantages	Disadvantages
1. Very effective in reducing speed	1. Cause "rough ride" to all drivers especially with certain skeletal problem
2. Relatively inexpensive	2. Increase delay time for emergency vehicles response
3. Can reduce traffic volume due to lower speed of vehicle	3. Potential increase in noise due to vehicle braking

(Town of Davidson, 2004)

2.4 Raised Crosswalks

Study by the HPU stated that raised crosswalk is a marked pedestrian crossing at an intersection or mid-block location constructed at a higher elevation than the roadway. It is more preferable for the pedestrians to cross the road with safety condition. Some of the benefits in using this structure are it can effectively reduce the vehicular speeds, less disruptive than humps, effective in reducing collision and improve visibility of pedestrian crossing *(Highway Planning Unit, Ministry of Works Malaysia, 2000)*.

The dimension specifications outlined by HPU are:

i. Width : 8m

ii. Height : 75mm to 100mm

iii. Gradient : 1:25

The profile of raised crosswalk is as shown in Figure 18.

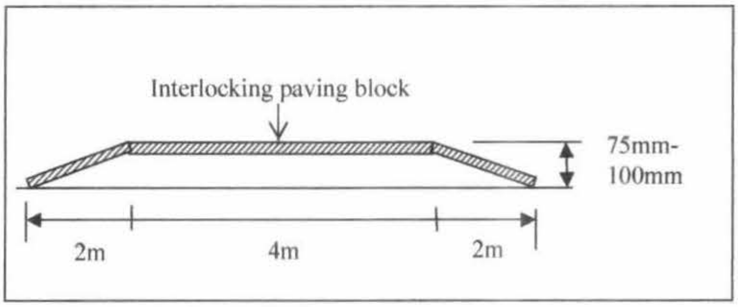

Figure 18: Raised Crosswalk Profile
(Highway Planning Unit, Ministry of Works Malaysia, 2000)

An example of raised crosswalk implemented in London is shown Figure 19 *(Town of San Anselmo, 2003)* and in Cambridge as in Figure 20 *(Town of Davidson, 2004)*. Advantages and disadvantages of raised crosswalks are described in Table 3.

Figure 19: Raised Crosswalk in London

Figure 20: Raised Crosswalk in Cambridge

Table 3: Advantages and Disadvantages of Raised Crosswalks

Advantages	Disadvantages
1. Reduce vehicle speed	1. May generate increased noise
2. Impoves pedestrian safety	2. Can require drainage modifications
3. Does not effect access	3. Generally results in 3 seconds delay for emergency vehicle
4. Flat portion can be textured	4. Often requires signage and markings

(Town of San Anselmo, 2003)

2.5 Levelling

Levelling is the procedure used to determine differences in elevation between points that are remote from each other. Elevation is a vertical distance above or below a reference datum. The reference datum is Mean Sea Level (MSL). The instruments used for this technique are Level and Levelling Staff. *(Transportation Engineering Department, 2008)*

In this project, levelling technique is used to determine the height of certain points on a hump. The data is used to construct the dimension profile of the humps.

2.6 Spot Speed Study

The work of Transport Research Laboratory (1993) states that there are three methods to measure speed of vehicles which are spot speed, average over distance and average over time. Spot speed data is used to establish trends for monitoring and are usually measured on links. The speed of vehicle can be collected by either radar speed gun or short base method. In short base method, a vehicle is timed for a known short distance, either using a stopwatch or automatically using modern loop or twin-tube devices. However, the presence of surveyors, equipment or unusual markings on the road surface can affect driver behaviour. This can be avoided by selecting suitable method and location for the survey.

CHAPTER 3

3.0 METHODOLOGY

3.1 Procedure Identification

3.1.1 *Data and Literature Review*

Literature review is done to collect relevant information on traffic calming measures. Most of the references used are foreign manuals on traffic calming studies and design guidelines from the Highway Planning Unit, Ministry of Works, Malaysia. UTP layout plan as shown in Figure 21 was obtained from the HSE department of UTP. The plan is needed to determine the location of road humps around the campus.

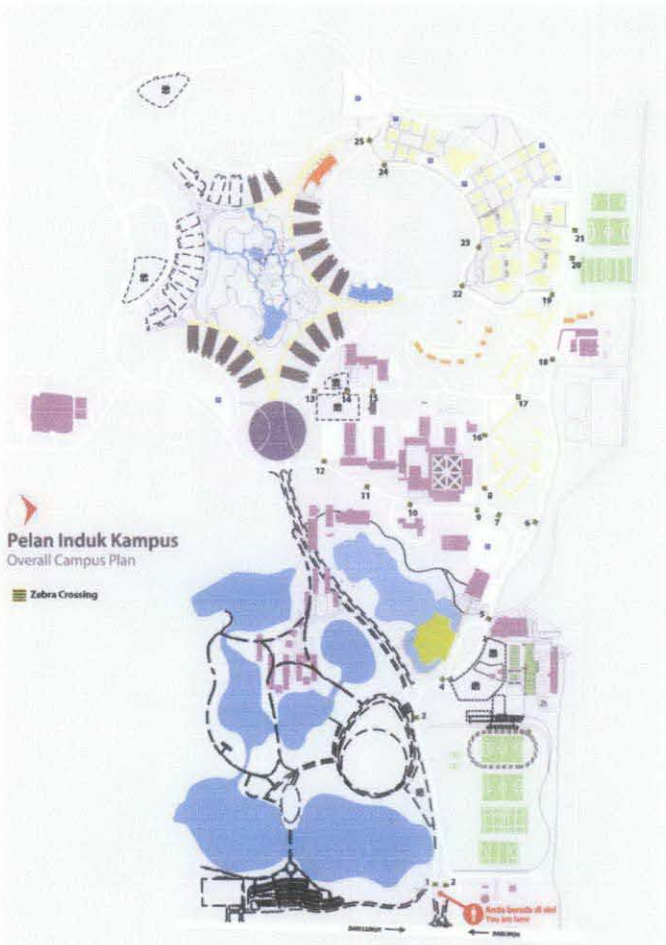

Figure 21: Plan Layout of Universiti Teknologi PETRONAS (UTP)

3.1.2 *Questionnaires*

The questionnaire used consists of 8 questions. The purpose of this survey is to get the feedback from the students on their driving behaviour, to determine current traffic condition in UTP and to obtain a brief observation on the effectiveness of the current traffic calming measures implemented in the campus. The last question of the survey is purposely to obtain any suggestion or recommendation to improve the traffic conditions of UTP. The questionnaires were distributed to 200 students. The respondents are expected to be consisting of 100 male students and 100 female students. Samples of the questionnaires are attached in the Appendix.

3.1.3 *Reconnaissance Survey*

Reconnaissance survey is conducted to provide an evaluation on the physical features of the study area. The purposes of this survey were to identify the locations of the road humps based on the layout plan, to select the road humps that will be used in the study, and to determine suitable locations to conduct spot speed survey. Other than that, the reconnaissance survey was conducted to observe possible situations to be the evidence of conflict where there are potential for accidents to occur. From the observation, the location where accidents will likely to occur can be determined. Pictures will be taken to record the physical features of road humps around the study area.

3.1.4 *Survey/ Data Collection*

The data collection process will be divided into two sections which are to measure dimension of the road humps and spot speed study using radar speed gun.

a) Dimension of road humps and raised crosswalks

The width of the humps can be measured using measuring tape. Figure 22 shows how the width of the hump is measured.

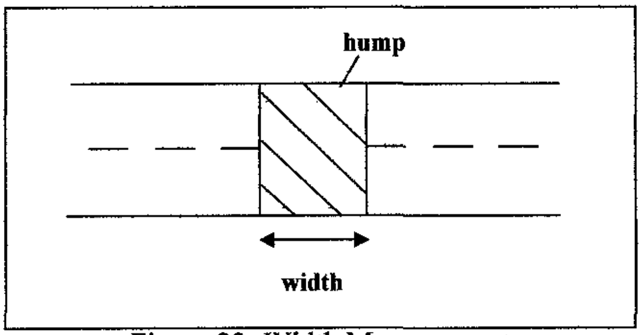

Figure 22: Width Measurement

Basic techniques on levelling will be done to determine the height of the road humps. A minimum of 2 persons are required to conduct this technique using level and levelling staff. This method is chosen out of others because it is proven to be the most accurate. The width of the hump will be divided into several sections. At every section, a person will hold the staff while the other person will measure the height. The heights of the hump for every section will be used to construct the hump profile. This procedure is illustrated in Figure 23.

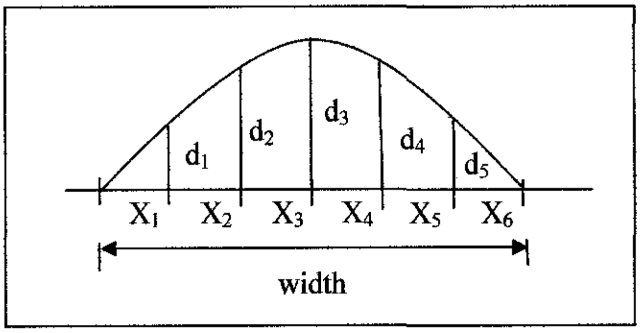

Figure 23: Height Measurement

b) Spot speed survey

The speed of vehicles at specified points will be determined using radar gun. In this survey, the raised crosswalks will be identified as road humps. Several points of specified distance will be measured and marked on the road. Using radar gun, the observer will capture the speed of vehicle when reaching a marked point along the travel path. This method will be repeated for the next point. This process can be illustrated as in Figure 24.

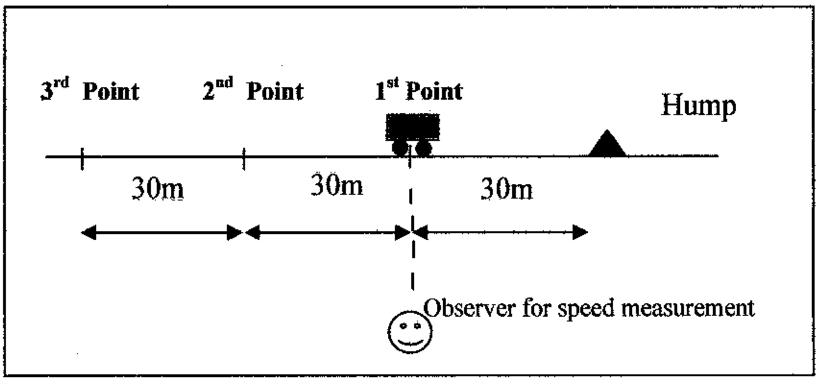

Figure 24: Illustrated process for Spot Speed Survey

This survey will be conducted in 2 phases which are:

i. Speed of vehicles when approaching a hump.

ii. Speed of vehicles when leaving a hump.

The survey will count for passenger cars only and the data obtained will be used in constructing speed profiles.

3.1.5 *Data Analysis*

The sources of data obtained are grouped in 3 categories which are the questionnaires, speed hump dimensions and the spot speed data.

i. Questionnaires

Answers of questionnaires will be analyzed in order to determine the responses from the students. One of the questions will ask the location of unsafe roads around UTP. This will provide a guide in determining the unsafe locations around UTP.

ii. Dimensions

A few sets of readings on the dimensions of the road humps will be collected and the dimension profile for the humps will be constructed. The profiles will be used to compare with the design specifications outlined by the Ministry of Works, Malaysia.

iii. Spot Speed Survey

From the survey, the obtained speed data will be used to construct a velocity-distance graph to represent speed profiles of the hump. The expected shape of the speed profile is shown in Figure 25.

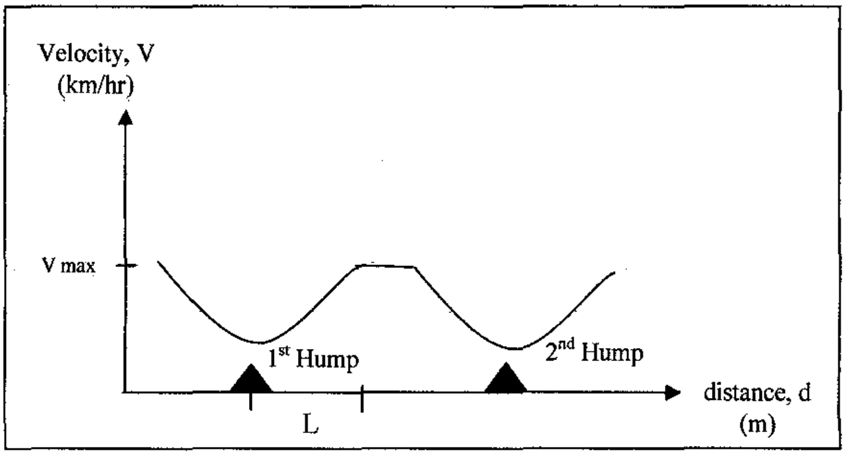

Figure 25: Expected result of Speed Profile

From the shape of the profile analysis can be conducted on:

- Determination of maximum velocity, V_{max}
  - V_{max} will be the maximum velocity achieved by the vehicle and should be within the speed limit of the study area. In this case, the speed limit around UTP is set at 40km/hr.
  - If V_{max} obtained is higher than 40km/hr, the vehicle is said to be speeding.

- Optimum spacing between humps, X
  - Distance to reach maximum velocity is represented by L. The optimum spacing between two humps, X is when it is equal to 2L.
  - If X>2L, there are excessive distance between the humps that allow vehicle to speed beyond the speed limit.
  - Thus, the optimum spacing can be determined by first specifying the distance to reach the desired speed limit.

3.2 Equipments

The following equipments involved in the project are:

i. Digital camera
ii. Radar Gun
iii. Measuring Tape
iv. Measuring Wheel
v. Level
vi. Levelling Staff
vii. Safety Vest

3.3 Hazard Analysis

During the data collection activities, there are several sources of hazards that might occur. Therefore, it is important to identify them and probable precautions that are relevant to be taken in order to avoid the hazards from occurring. Table 4 summarizes hazard analysis of the project.

Table 4: Hazard Analysis

Area of Work	Person Exposed	Source of Hazards	Method to Counter
1. Measuring dimension	the observer	moving vehicles	wear safety vest to be easier to be seen
2. Spot Speed Survey	the observer	moving vehicles	suitable choice of survey method and location of observer
	the driver	change of driver behaviour towards unusual markings and equipments	
3. Throughout survey	the observer	Dust (during dry period)	wear mask

CHAPTER 4

4.0 RESULTS AND DISCUSSION

4.1 Reconnaissance Survey

Based on the layout plan obtained from the HSE department, a reconnaissance survey was conducted to determine the exact locations of the road humps. It is found that there are a total of 25 humps located around UTP. The locations of these humps were shown in the layout plan obtained earlier. In this study, the main route which started from the main entrance until back of Village 5 consists of 14 road humps and raised crosswalks. The selected route of study was divided into four sections. Figure 26 and Figure 27 show raised crosswalk and road hump in UTP. Figure 28 shows the exact locations of road humps around UTP and the selected 14 humps for the project.

Figure 26: Raised Crosswalk in UTP

Figure 27: Road Hump in UTP

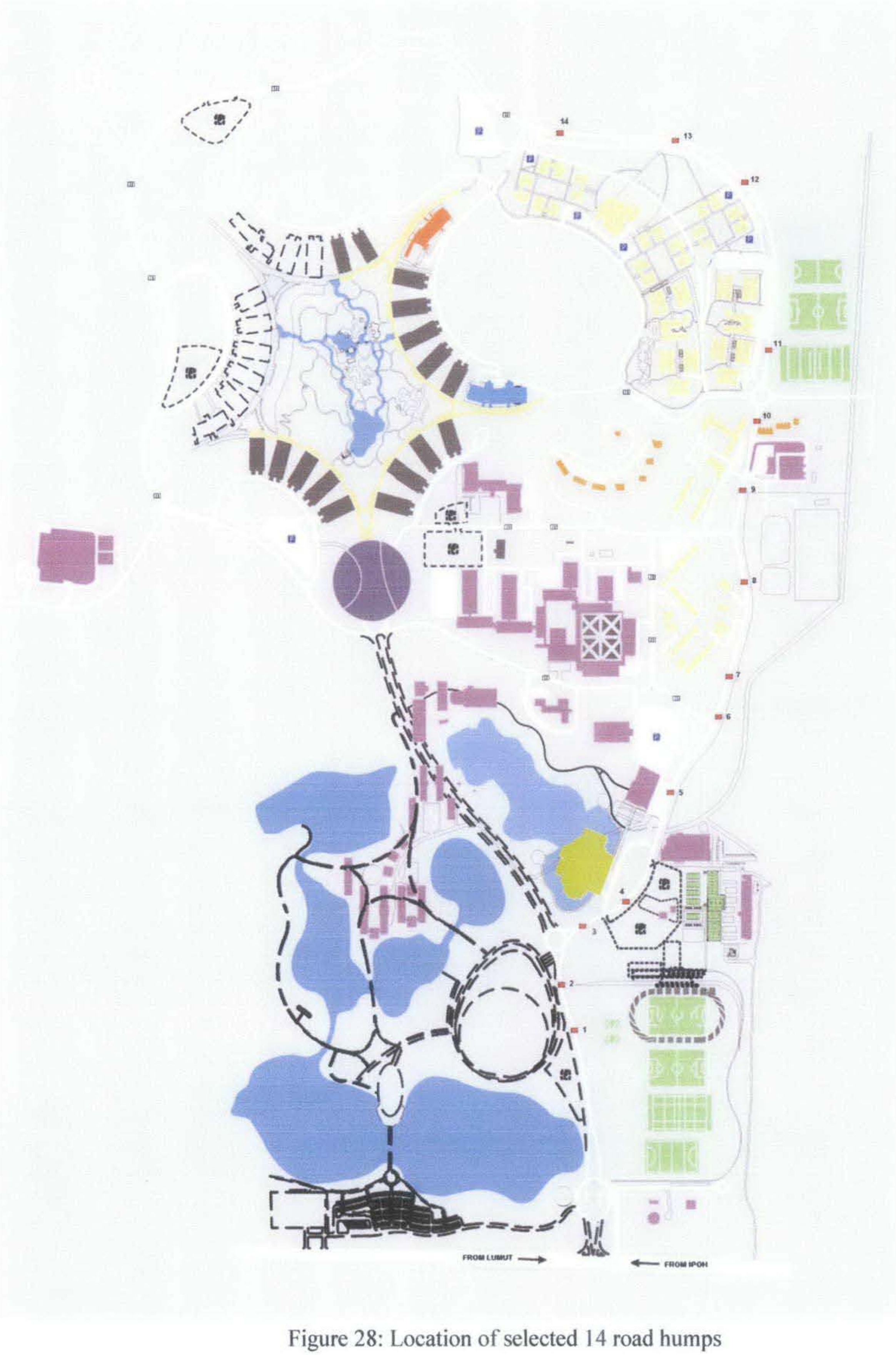

Figure 28: Location of selected 14 road humps

4.2 Analysis on questionnaires

4.2.1 *Types of transport used by students*

Question 2 of the questionnaire is expected to give a brief percentage of students that have various types of transportation. Figure 29 and figure 30 shows the distribution on male and female students with transport in UTP.

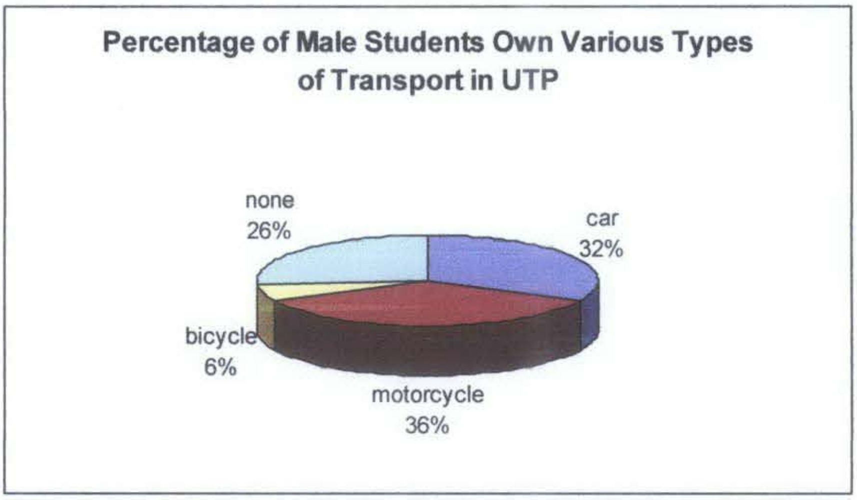

Figure 29: Distribution on Male Students Own Transport in UTP

The 200 respondents are assumed to be representing the whole community of students in UTP. The result of the questionnaire shows that 36% of the male students use motorcycle as their main transport in UTP. From 100 male students, 32% of them use car, 6% use bicycle and the remaining 26% do not have any transport.

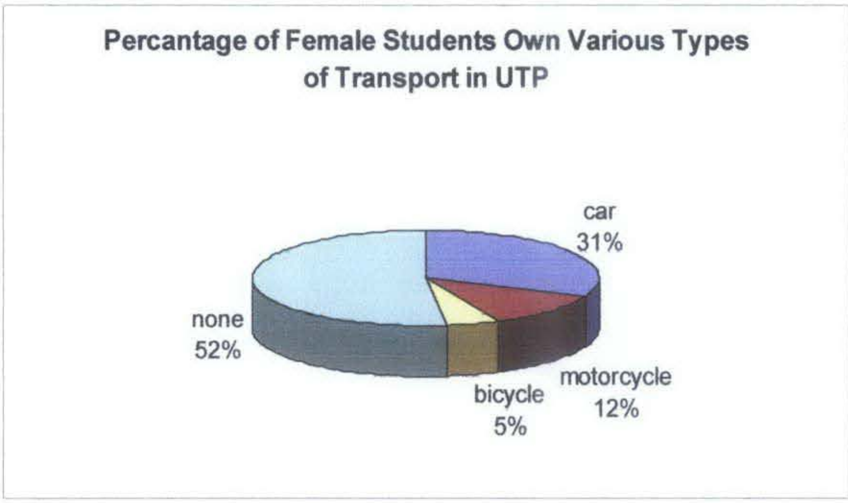

Figure 30: Distribution on Female Students Own Transport in UTP

The result differs for female students where more than half of 100 female students do not have any transport, 31% of them have car, 12% use motorcycle and the other 5% use bicycle.

4.2.2 *Driving behaviour of students*

Driving behaviour of the students was evaluated through questions 3, 4 and 5 and the result is shown in Figure 31.

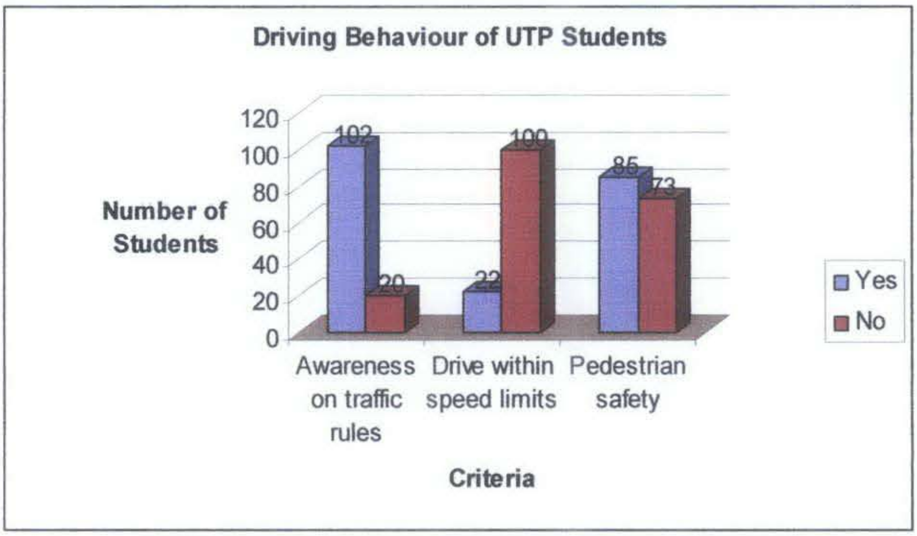

Figure 31: Distribution of Students' Driving Behaviour

The evaluation on student's driving behaviour was determined based on three questions asked in the questionnaire. From the 122 respondents that drive in UTP, 102 of them are aware of the traffic rules in UTP. 100 of the students admit that they do not drive within the speed limits while only 22 students obey the speed limits. From the 200 students, 73 of them agreed that cars in UTP are too fast and not safe for the pedestrian, 85 students agreed that it is safe to walk within the campus while the remaining 42 students said that the level of safety of the roads are moderate.

4.2.3 *Feedback from students on the effectiveness of road humps*

Question 6 of the questionnaire reflects the feedback of the students on the effectiveness of road hump implementation. Figure 32 summarizes the result.

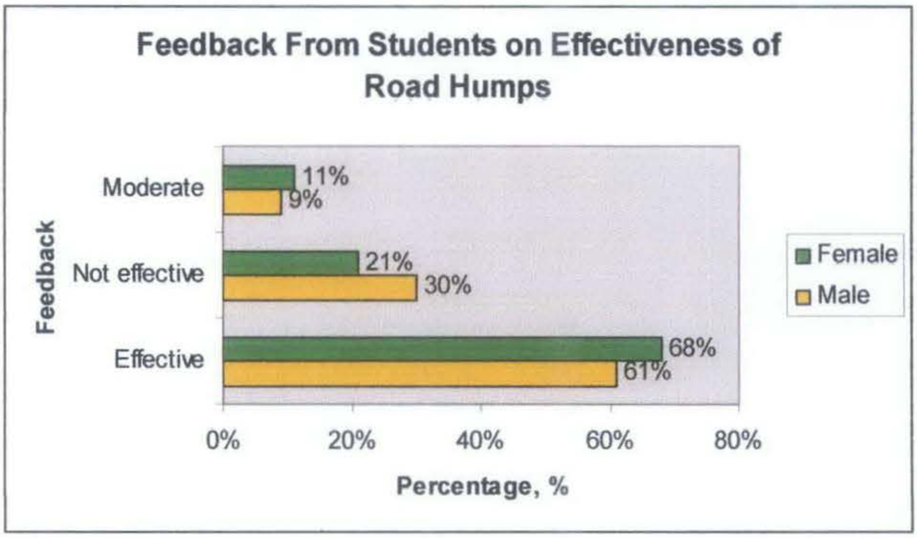

Figure 32: Effectiveness of Road Humps in UTP

From the 200 respondents, 68% of female and 61% of male students agreed that the existing road humps are effective in reducing speed of vehicles. 21% of female students and 30% of male students realized that the speeding problem can not be solved using the road humps.

4.3 Dimension

4.3.1 *Hump width*

The width of the hump and crosswalks were measured using the 300M-measuring tape. The results obtained are as shown in Table 5.

Table 5: Width of Road Humps

No. of Hump	Width (m)
Hump 1	2.40
Hump 2	5.90
Hump 3	6.20
Hump 4	6.06
Hump 5	3.13
Hump 6	3.90
Hump 7	6.06
Hump 8	4.05
Hump 9	3.16
Hump 10	2.40
Hump 11	2.70
Hump 12	2.83
Hump 13	1.92
Hump 14	2.40

Humps 2, 3, 4 and 7 are raised crosswalks while the other ten humps are normal round-top road humps. Based on the design specification by HPU, the optimum width of round-top road humps is between 3.7 metres and 4 metres while for raised crosswalk, the maximum width is 8 metres. However, the results in Table 5 show that only Hump 6 and Hump 8 met the optimum width of the design specification. Other road humps are too short in width thus will more likely result the humps to be more abrupt. All existing raised crosswalks achieved the optimum width.

4.3.2 *Hump Profile*

The height of the road hump was measured using levelling equipments which are level and staff. The height of hump for every interval of 0.3m width was measured. The data obtained from measuring the height and width of the road humps will be used to construct the profile for each hump. The hump profiles for these humps are shown in Figure 33 to Figure 46.

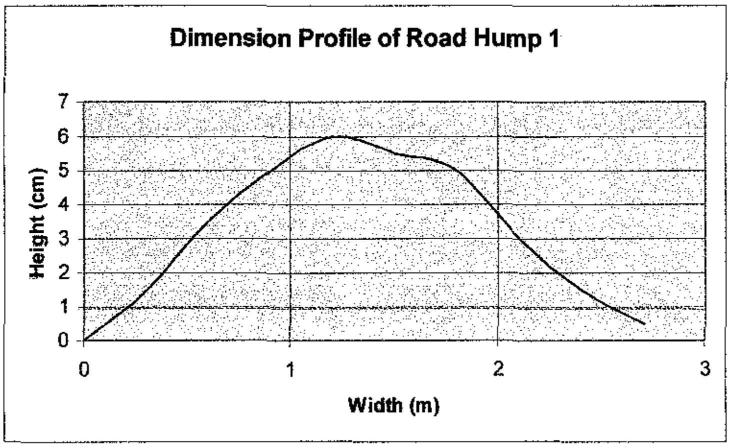

Figure 33: Profile of Road Hump 1

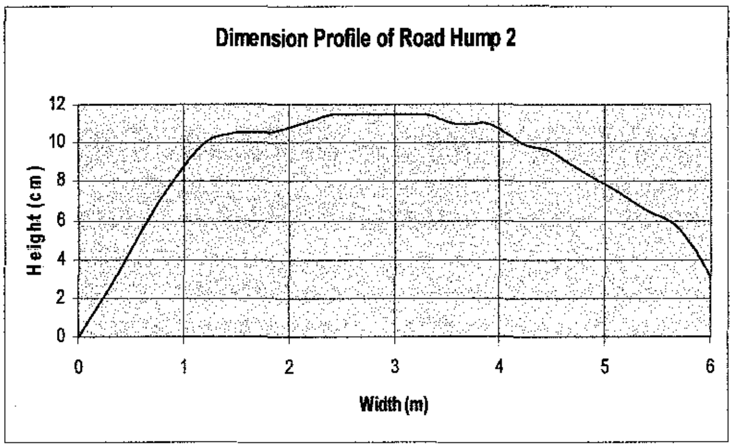

Figure 34: Profile of Road Hump 2

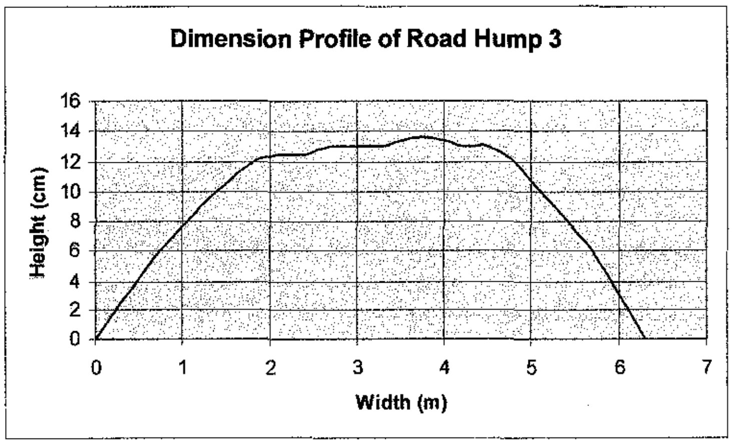

Figure 35: Profile of Road Hump 3

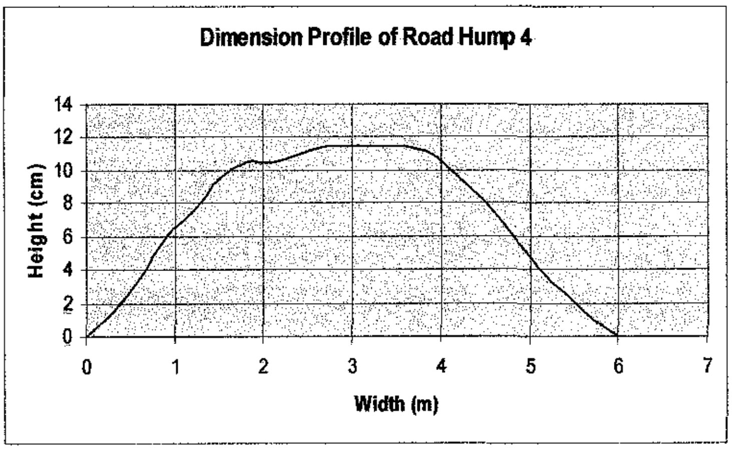

Figure 36: Profile of Road Hump 4

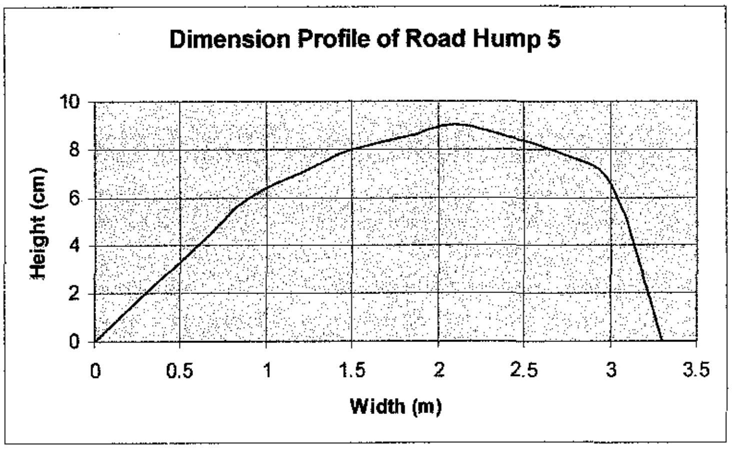

Figure 37: Profile of Road Hump 5

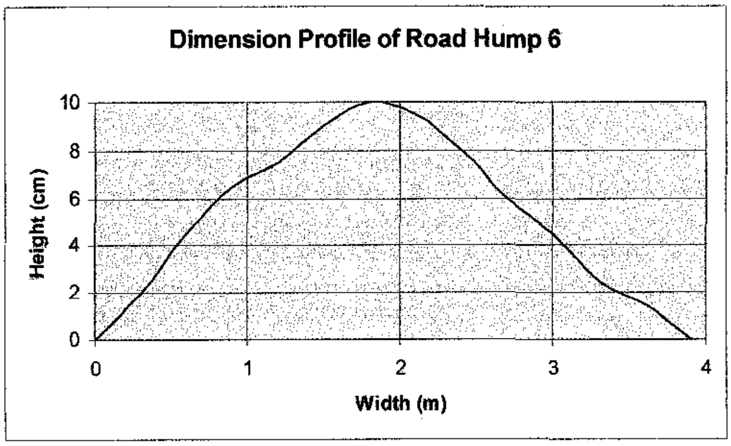

Figure 38: Profile of Road Hump 6

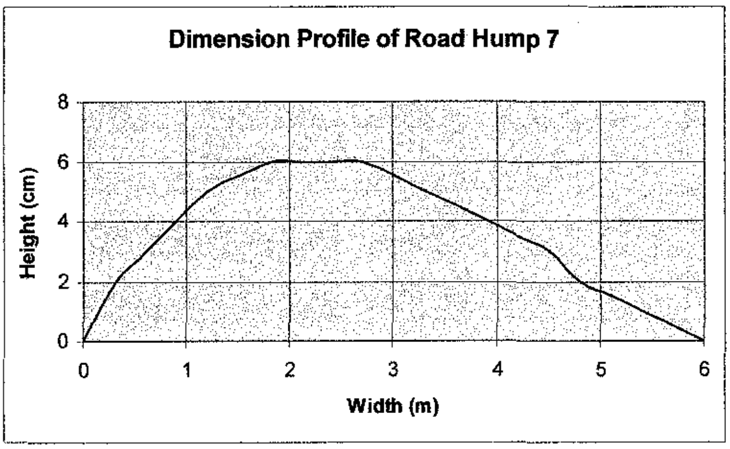

Figure 39: Profile of Road Hump 7

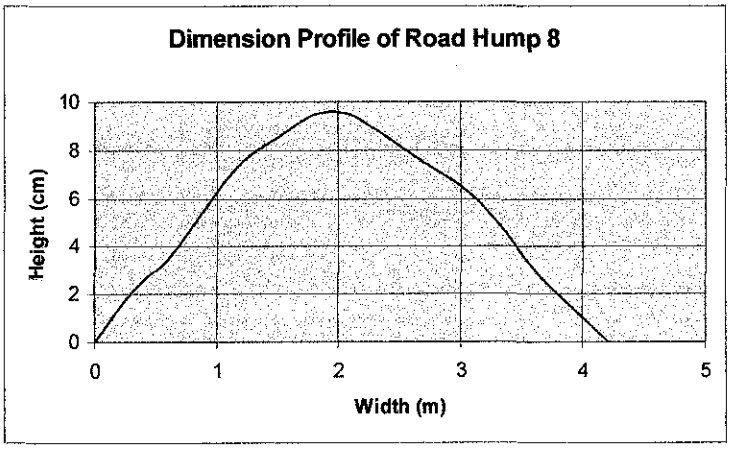

Figure 40: Profile of Road Hump 8

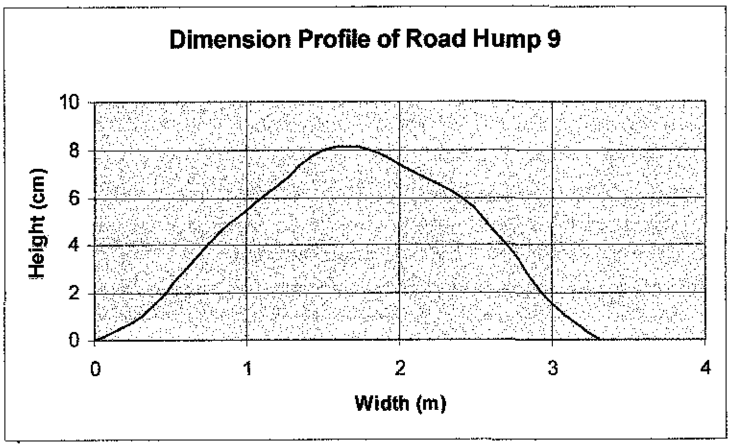

Figure 41: Profile of Road Hump 9

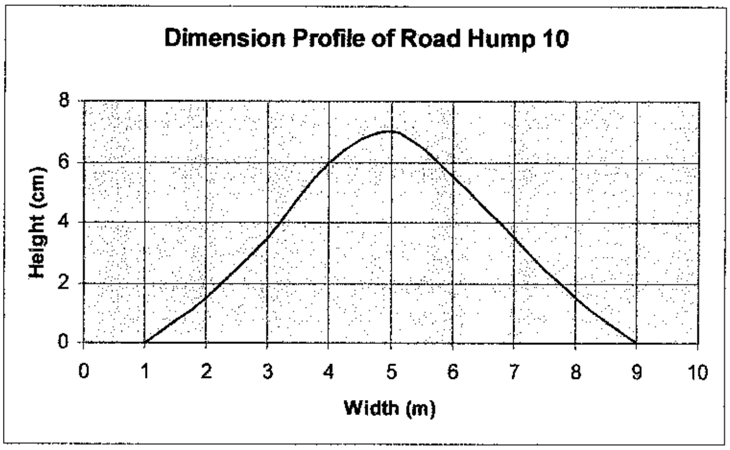

Figure 42: Profile of Road Hump 10

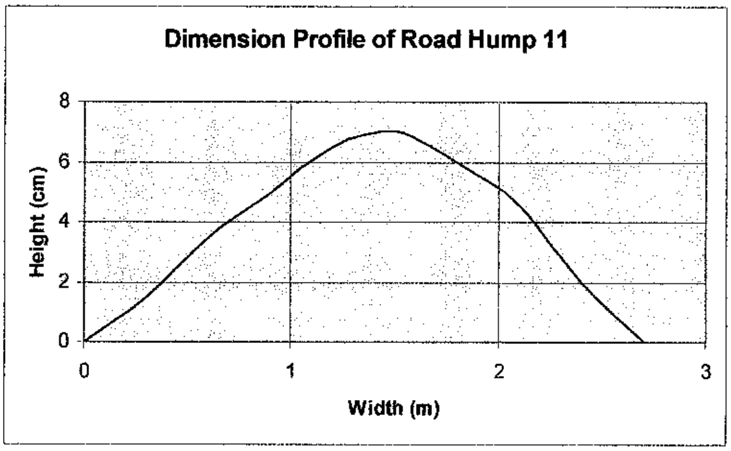

Figure 43: Profile of Road Hump 11

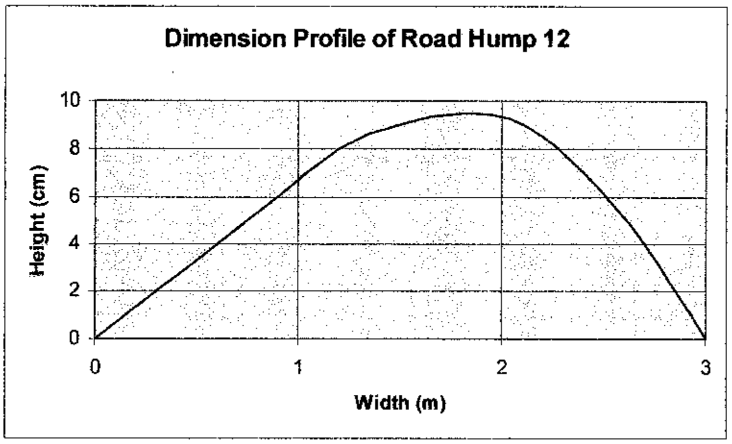

Figure 44: Profile of Road Hump 12

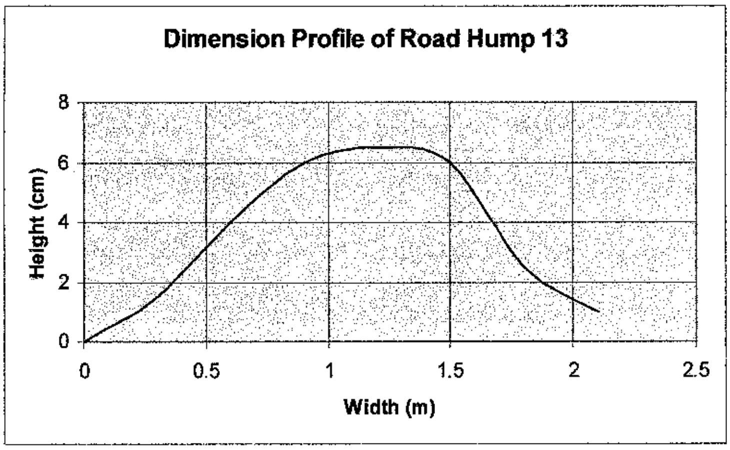

Figure 45: Profile of Road Hump 13

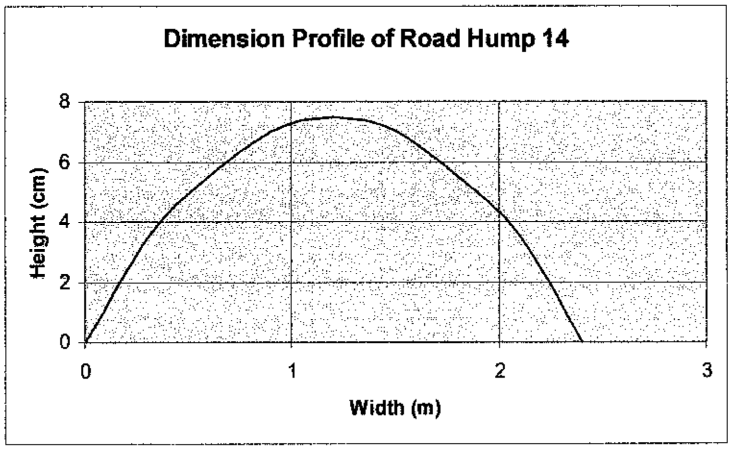

Figure 46: Profile of Road Hump 14

The optimum height of road hump and raised crosswalks should be in the range of 7.5cm to 10.0cm. However, the dimension profiles show that raised crosswalks at Humps 2, 3 and 4 had exceeded the maximum height.

4.4 Spot Speed Study

The spot speed survey was conducted at five different locations along the major route from entrance to the back of Village 5 in both directions of travel. The five locations are:

i. From Hump 1 to Hump 2
ii. From Hump 4 to Hump 5
iii. From Hump 8 to Hump 9
iv. From Hump 9 to Hump 10
v. From Hump 11 to Hump 12

Every session of the survey was done during weekdays and during off-peak hours to obtain the free flow traffic. The speed data obtained are used to construct the speed profiles as shown in Figure 47 and Figure 48.

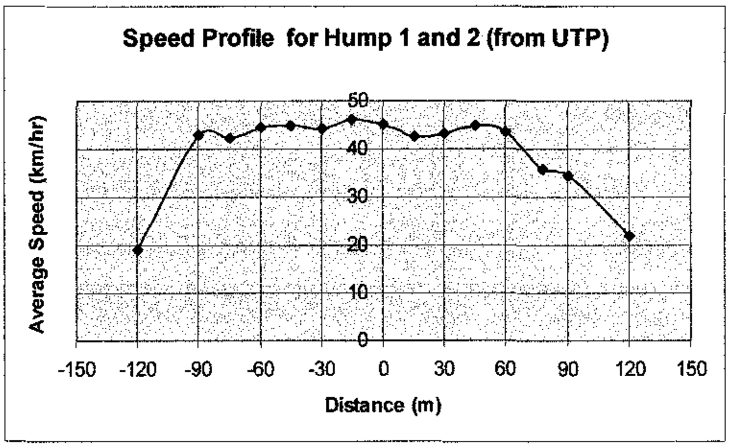

Figure 47: Speed Profile for Hump 1 and 2 (from UTP)

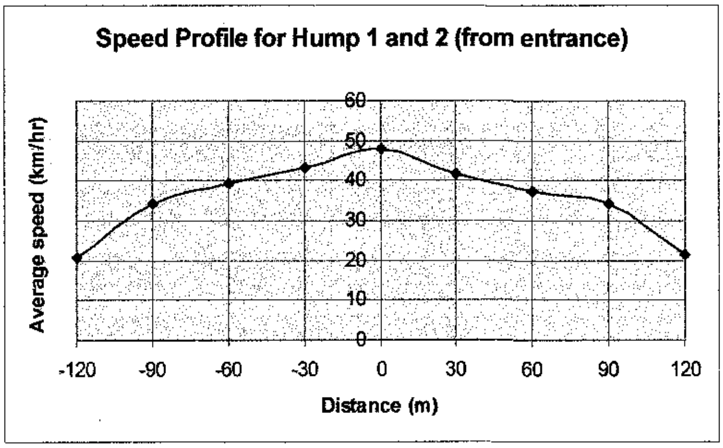

Figure 48: Speed Profile for Hump 1 and 2 (from entrance)

Figure 47 is the speed profile for traffic flow from UTP towards the main entrance gate or from Hump 2 towards Hump 1. Point -120m represents Hump 1 while point 120m represents Hump 2. Point 0 is the centre point between both humps and the distance between Hump 1 and Hump 2 is 240 metres. The car travels at about 30m after leaving the first hump to reach speed limit of 40 km/hr. The car will accelerates for a certain distance before the speed decreases as it approaching the second hump.

From the shape of the speed profile obtained, it shows that the car has an approximately 160 metres of distance to accelerate or travel beyond the speed limit of 40km/hr. Thus the optimum distance between Hump 1 and Hump2 for the vehicle to travel from UTP towards the entrance within the speed limit should be about 80 metres.

The spot speed survey was done for both directions of travel to find the average optimum distance between two humps. Figure 48 represents the speed profile for Hump 1 and Hump 2 for traffic flow from the entrance. It shows that the optimum distance between Humps 1 and 2 is about 130 metres. Therefore, the average optimum distance between Hump 1 and Hump 2 for both directions of travel is about 100 metres. Speed profiles for other locations of the study are as in Figure 49 to Figure 56.

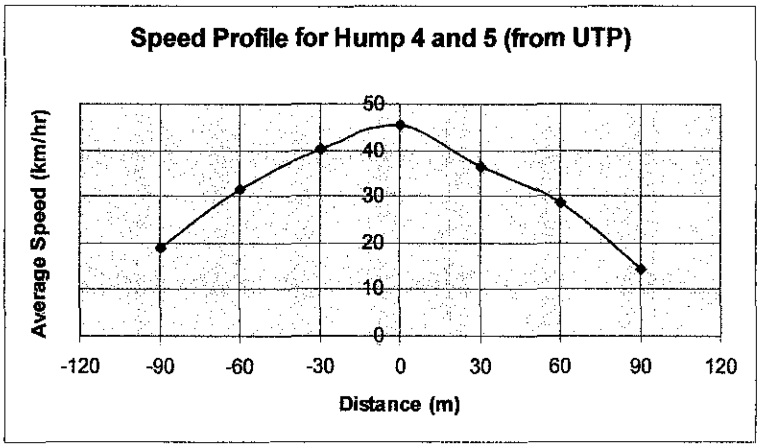

Figure 49: Speed Profile for Hump 4 and 5 (from UTP)

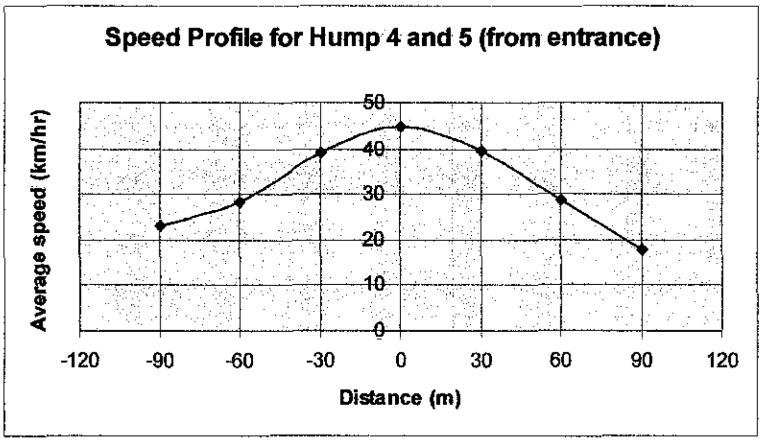

Figure 50: Speed Profile for Hump 4 and 5 (from entrance)

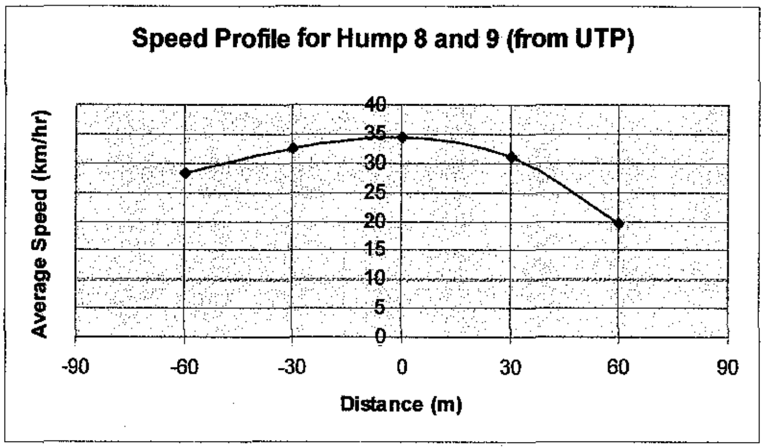

Figure 51: Speed Profile for Hump 8 and 9 (from UTP)

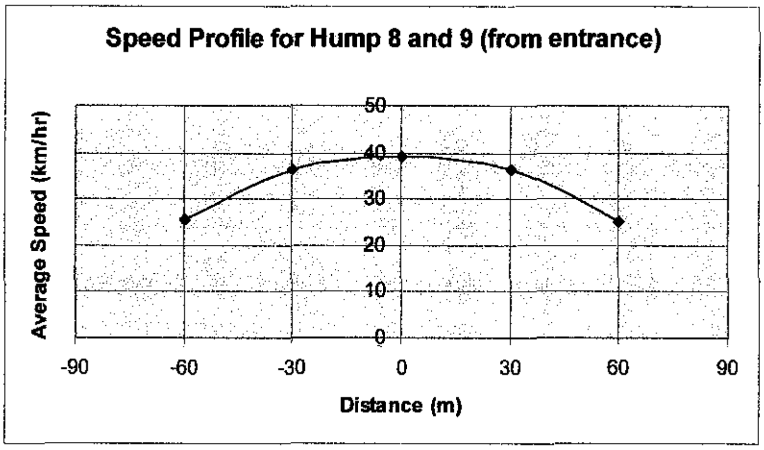

Figure 52: Speed Profile for Hump 8 and 9 (from entrance)

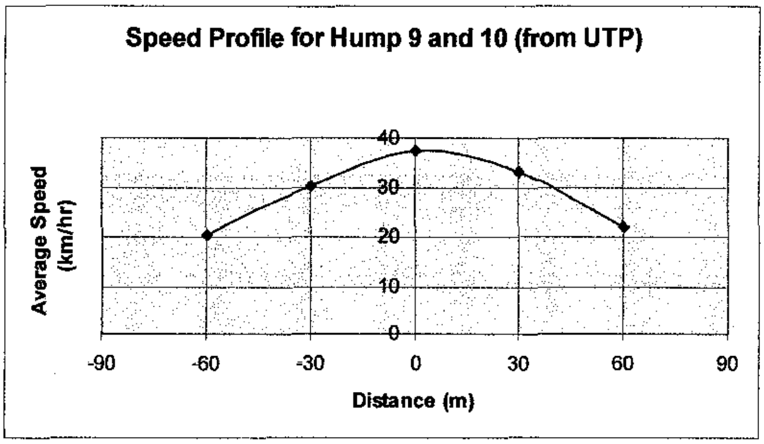

Figure 53: Speed Profile for Hump 9 and 10 (from UTP)

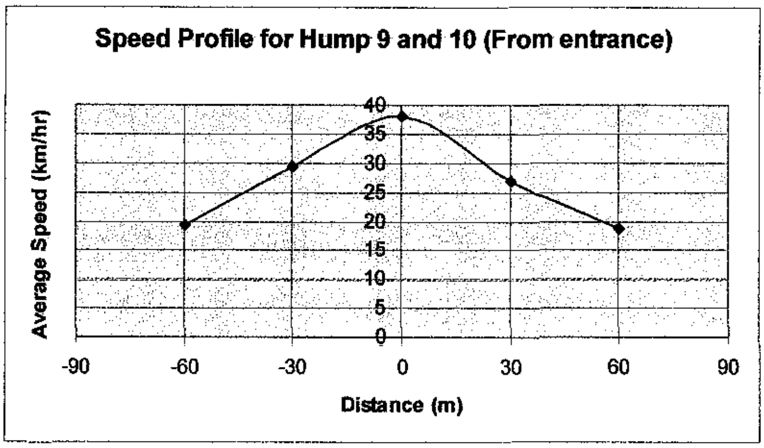

Figure 54: Speed Profile for Hump 9 and 10 (from entrance)

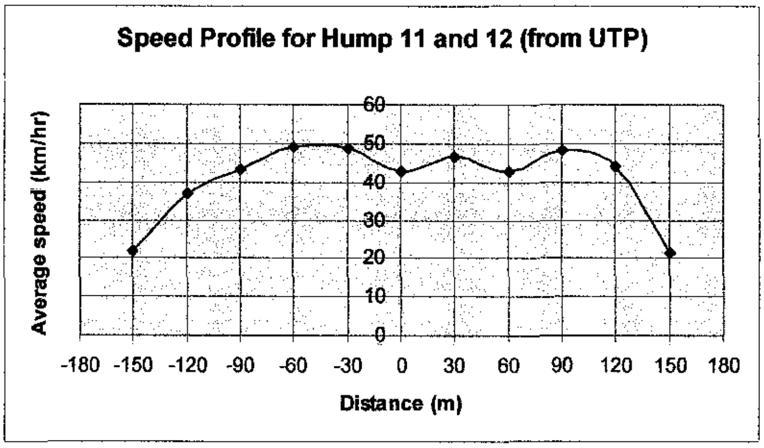

Figure 55: Speed Profile for Hump 11 and 12 (from UTP)

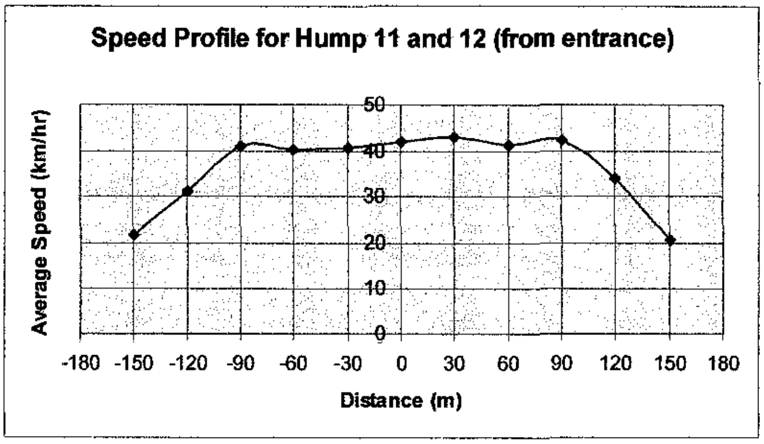

Figure 56: Speed Profile for Hump 11 and 12 (from entrance)

The same analysis was done for the speed profiles obtained for the other four locations. The results of the analysis are summarized in Table 6.

Table 6: Summary of results

Hump	Max. Speed	Within Speed Limit	Existing Distance	Proposed Distance
1 & 2	45 km/hr	No	240m	100m
4 & 5	45 km/hr	No	180m	120m
8 & 9	40 km/hr	Yes	120m	None
9 & 10	38 km/hr	Yes	120m	None
11& 12	50km/hr	No	300m	100m

The results show that most drivers had exceeded the speed limit of the campus at three locations of the study. However, the proposed optimum distance for the humps is different for every location. For Hump 1 and Hump 2, the optimum distance proposed is about 100metres. For Hump 4 and Hump 5, the distance is longer which about 120 metres. This situation might be influenced by the dimension of the humps themselves. Based on the result of the dimension profiles, Hump 5 is steeper than Hump 1 while heights of Hump 2 and Hump 4 are about the same.

At steep humps, longer distance between humps is required as the drivers will tend to slow down when approaching those humps. On the other hand, most drivers tend to neglect the existence of gradual humps hence the optimum distance between these humps will be shorter.

With the same reason as Hump 1 and Hump 2, the gradualness of Humps 11 and Hump 12 caused the proposed optimum distance between the humps to be about 100 metres. The existing Humps 8, 9 and 10 are located at appropriate locations since drivers travel passing these humps within the speed limit of 40km/hr.

CHAPTER 5

5.0 CONCLUSION AND RECOMMENDATION

5.1 Conclusion

The result of the survey on UTP students selected in random shows that the students are aware of the traffic condition of UTP. Most of them can even evaluate or comment on their own driving behaviour. In most of the feedback obtained, the students gave positive responds by suggesting various ways to improve the traffic conditions in UTP. This had reflected a positive sign that the study had been accepted by the students.

Study on the dimension of the existing road humps and raised crosswalks shows that some of the structures do not meet the design standards outlined by HPU. Road humps that are short in width will cause the humps to be abrupt and not favourable to be passed through. Raised crosswalks which are higher than the specified design might cause damage to the bottom part of the car as complained by the students.

The results of the study show that the existing traffic calming structures could not reduce the speed of vehicles effectively. The analysis of the results obtained proved that dimension of the structures had influenced the speed of vehicles. The possibility for the drivers to slow down as they approaching steep humps is more likely compared to when at gradual humps. Thus the proposed optimum distance for gradual humps theoretically will be shorter in order to ensure that the drivers drive within speed limit.

5.2 Recommendation

The initial decision made for the project was to conduct the study on a specific route that started from the main entrance till to the back of Village 5. This route is assumed to be the main route that occupies most of the traffic. This route covers 14 road humps and crosswalks out of the total 25 of the structures allocated around UTP. However, it is recommended to conduct the study on all road humps and crosswalks if time is permissible. This is to justify the characteristics of every hump or crosswalk and to study the behaviour of the drivers towards each structure.

The presence of observer during the spot speed survey will alter the driver's behaviour where they will tend to slow down as they notice the observer. Therefore, it is recommended for the observer to find the suitable locations for not to be seen by other road users especially the drivers. Some examples of suitable locations are behind the bushes and at the bus stop.

The reliability of the equipment is another factor to be considered. During rainy days, the radar gun could not be used to capture data thus will affect the data gathering process. If further study to be conducted in the future, it is recommended that other types of equipment to be used to capture speed of vehicles such as portable traffic counter.

Improvement on method of measurement should be done to ensure that the data obtained in finding measurement of the profiles are accurate. For example, in spite of using measuring tape to measure the distance between humps, the author managed to obtain a measuring wheel for that purpose which is more accurate.

It is recommended to have the existing road humps and raised crosswalks in uniform shapes and distances based on the result of the study. There are also other traffic calming structures that are potential in reducing speed of vehicles such as double hump, chicanes and rumble strips.

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APPENDICES

APPENDIX A: Questionnaire Form.

APPENDIX B: Photos.

APPENDIX A

QUESTIONNAIRE FORM

SURVEY FOR FINAL YEAR PROJECT

Village/Block: ___________ Gender: Male/ Female

The purpose of this form is to obtain feedback on the current traffic condition and the effectiveness of **road bumps** in reducing the speeding problems in UTP.

1. Are you a staff/student of UTP? *(Please circle the appropriate answer)*

   a. Staff
   b. Student

2. Do you use any transport in UTP? *(Please circle the appropriate answer)*

   a. Car
   b. Motorcycle
   c. Bicycle
   d. None

   If you answer a or b in question 2, please answer questions 3 and 4. Otherwise, kindly proceed to question 5.

3. Are you aware of the traffic rules (Speed limit, warning signs etc.) in the UTP? *(Please circle the appropriate answer)*

   a. Yes
   b. No

4. Do you always ensure that you drive within the speed limit (40km/hr) in the campus? *(Please circle the appropriate answer)*

   a. Yes
   b. No

5. Do you think that the students drive safely in the campus? Why?

   a. No – The cars are too fast and accidents occur
   b. Yes – It is safe to walk within the campus
   c. Others: ______________________________

6. Do you think that the **road bumps** in UTP had successfully reduced the speed of the cars/motorcycles?

   a. Yes – Students will slow their cars/motorcycles when reach the bumps
   b. No – The bumps do not affect the students driving behaviour
   c. Others: ______________________________

7. Where in UTP (location) do you think the road is dangerous to the users?

   ____

8. Do you have any suggestion on how to improve the traffic conditions in UTP?

   ____

Thank you for your cooperation and have a nice day!!

*** Please pass this form to the front of class. TQ...**

APPENDIX B

PHOTOS

Figure 57: Measuring wheel

Figure 58: Radar gun

Figure 59: Measuring height using levelling technique

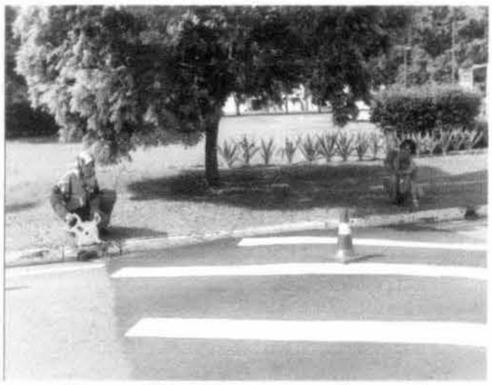

Figure 60: Measuring dimension using measuring tape

Figure 61: Spot speed survey

Figure 62: Measuring dimension using measuring wheel

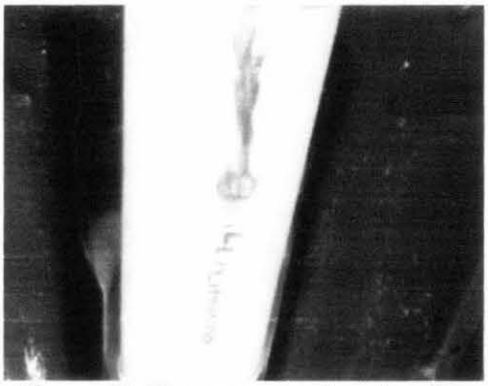

Figure 63: Damage on exhaust surface because of high humps

Figure 64: Scratch mark on hump

ENGINEERING DESIGN EXHIBITION 22

Certificate of Appreciation

This certificate is awarded to

NUR ADILAWATI BINTI MOHD ROSLAN
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Director of Undergraduate Studies
Universiti Teknologi PETRONAS