COMPARATIVE STUDY OF TRAFFIC CALMING DESIGN PROCESS

Farzana RAHMAN  
Student  
Graduate School of Engineering  
Saitama University  
255 Shimo-Okubo, Saitama, 338-8570 Japan  
Fax: +81-48-855-7833  
E-mail: farzana@dp.civil.saitama-u.ac.jp

Hisashi KUBOTA  
Professor  
Graduate School of Engineering  
Saitama University  
255 Shimo-Okubo, Saitama, 338-8570 Japan  
Fax: +81-48-855-7833  
E-mail: hisashi@dp.civil.saitama-u.ac.jp

Kunihiro SAKAMOTO  
Research Associate  
Civil and Environmental Engineering  
Saitama University  
255 Shimo-Okubo, Saitama, 338-8570 Japan  
Fax: +81-48-855-7833  
E-mail: sakamoto@dp.civil.saitama-u.ac.jp

Abstract: Residents sometimes feel general decline in life due to speedy traffic on neighborhood streets and high traffic volume. Traffic calming is a way to reduce traffic speeds and volume into local residential streets and thereby increase safety for all road users. Japan has introduced some traffic calming devices but there is no design guideline as well as documented methodology for the process. The objective of this research is to perform a comparative study of traffic calming design process, which is expected to facilitate for future implementation in Japan. An internet based questionnaire survey of North America and some European countries was conducted to have knowledge of the traffic calming design process and types of devices currently in use. Interview survey was done to Sacramento (California) and Largo (Maryland) USA. From the research it was found that speed hump is most widely used (53%) device having speed reduction effect of about 8mph.

Key words: Traffic calming, guideline, design process

1. INTRODUCTION

Excessive speed and high traffic volume are the most common problems reported on residential streets. Traffic calming is a term most commonly associated with physical features placed on a roadway to influence vehicle speed and the cut-through traffic volume. Thus the purpose of traffic calming is to improve safety and comfort levels for pedestrians as well as for motor users into residential streets.

Experience throughout Europe, Australia, and North America has shown that traffic calming, if done appropriately can reduce traffic speeds and the number and severity of crashes. Most of the developed countries such as the USA, the UK, Canada, Netherlands, Australia, and South Africa have organized schemes for conducting the traffic calming design process. Whereas most of the Asian countries such as Japan does not have any design guideline to facilitate the traffic calming scheme. Several traffic calming devices are installed in Japan but most of them are not so effective as they do not follow proper research method. Therefore, a guideline must be set for the proper selection and installation prior to the implementation of any traffic calming device. Thus, the objective of this research is to perform a comparative
study of traffic calming design process, which is expected to facilitate for future implementation in Japan.

Goal of traffic calming is to increase safety for all road users including pedestrians, cyclists and motorists. It improves road conditions for people and enhances livability of neighborhood. The principal objective of traffic calming is to attain slow vehicular speeds, protect neighborhood areas from the unwanted through traffic, reduce the environmental pollution caused by motor vehicles and reduce the crash occurrence and severity.

2. TRAFFIC CALMING IN JAPAN

The Japanese experimented with “Woonerven” and some other traffic calming devices in recent years. The first "Community Street” was installed in Nagaike-cho, a suburb of Osaka, based on the Woonerf design in 1980. Pedestrian traffic in the street increased by 5 percent, bicycle traffic rose by 54 percent and car traffic entering the street fell by 40 percent. Average vehicle speeds were as low as 5 km/hr (3 mi/hr), with a maximum speed observed of 8 km/hr (5 mi/hr). Over 90 percent of residents highly praised the community street. In 1984, the Japanese moved on to area-wide traffic calming with the "Road-Pia" concept, whereby safety and comfort were secured for pedestrians and residents. The principle was tested in the Koraku section of Minato-ku, Nagoya.

Japan has introduced “Community Zone” or Zone 30 in 1996. There are 160 Community Zones in Japan. Among these 62 projects were completed in 2001 and many of them are ongoing project. Speed humps, chokers, chicanes were introduces as supporting measures to reduce speed in Community Zones. In 2003 Japan started new version of Community Zone named “Kurashino Michi Zone”. This concept was almost similar to the Community Zone.

3. STUDY METHODOLOGY

Study resources included in this research are questionnaire survey through internet, mail based survey, interview survey and manual study. To obtain traffic calming information and experience, manuals from several communities in the United States and Canada were studied. Traffic calming experiences from some communities in Europe; South Africa and Australia were also studied from their manuals.

A questionnaire survey of USA, some European countries and some cities of Canada was conducted about the traffic calming design process and types of devices currently in use on the residential local streets. Interview survey conducted in Sacramento (California) and Largo (Maryland) USA which included the description of the traffic calming process and issues, question and answer and sight visit to see traffic calming devices presently used by them. Traffic calming process manuals and/or policies is studied for most of the cities to which questionnaires were sent for clear understanding of the process. About 175 questionnaires were sent and 26 replies received. Among the 26 returned questionnaires 19 were from several states of USA, 3 from Canada and 4 from Europe.
3.1 Questionnaire Survey

The questionnaire survey was conducted through e-mail from 22nd September 2004 to North America and some European countries and it was conducted to the decision making authorities (for example for USA it is named as US Department of Transport). The questionnaire survey included 11 questions subdivided into two parts regarding to traffic calming design and decision making process. The questionnaire consists of questions regarding to the instigation and frequency of acceptance of traffic calming requests, existence of clear decision making process and presence of traffic calming manuals, source of budget for traffic calming projects, potential support and opposition for traffic calming device, duration of one project and frequency of efficiency confirmation for the devices. This article primarily focuses on the traffic calming design process.

Several typological analyses were conducted from the questionnaire survey data. Respondents’ comments are also studied for the clarification of the traffic calming process. The trend of used devices by different regions of North America was observed from the questionnaire survey, which is described in Table 1. Different countries use several types of traffic calming devices. From the questionnaire survey the tendency of used devices by different cities was found. Table 1 shows the percentage of devices exercised by different cities.

<table>
<thead>
<tr>
<th>Name of Province, State</th>
<th>Name of the devices used (Percentage)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Speed humps</td>
</tr>
<tr>
<td>Austin, TX</td>
<td>14%</td>
</tr>
<tr>
<td>Concord, NH</td>
<td>25%</td>
</tr>
<tr>
<td>Delray-beach, FL</td>
<td>30%</td>
</tr>
<tr>
<td>Overland Park, KS</td>
<td>27%</td>
</tr>
<tr>
<td>Sacramento, CA</td>
<td>50%</td>
</tr>
<tr>
<td>Seattle, WA</td>
<td>7%</td>
</tr>
<tr>
<td>West Sacramento, CA</td>
<td>85%</td>
</tr>
<tr>
<td>Boulder, CO</td>
<td>50%</td>
</tr>
<tr>
<td>Dover, DL</td>
<td>50%</td>
</tr>
<tr>
<td>Redmond, WA</td>
<td>25%</td>
</tr>
<tr>
<td>Largo, MD</td>
<td>75%</td>
</tr>
<tr>
<td>Sarasota, FL</td>
<td>85%</td>
</tr>
<tr>
<td>Vancouver, BC</td>
<td>30%</td>
</tr>
<tr>
<td>Colorado Springs, CO</td>
<td>25%</td>
</tr>
<tr>
<td>Albuquerque, NM</td>
<td>96%</td>
</tr>
</tbody>
</table>

Amongst the devices commonly used approach can be observed. From the survey it was found that speed hump is most widely used (53%) device. Then traffic circles (20%) were used mostly, and then speed tables (13%), speed cushions (7%), and other device (7%) were used usually. Speed hump is the most widespread traffic calming devices because of its effect in speed reduction and its low cost. In case of City of Albuquerque, NM 96% of all devices is speed hump. For city of Sarasota Florida 85% of the devices used are speed tables and for
West Sacramento California 85% devices are speed hump.

Other devices sharing 80% by Austin, Texas includes speed cushions and some with raised median. City of Concord, NH use bulb-outs as others device. City of Redmond, WS mentioned medians, etc as used others device. Rest of the cities did not mention the name of the devices under the category of other device. Some of cities do not have the breakdown of the devices used by them.

Netherlands do not have a national inventory of all intersections, type of control, calming measures etc and cannot therefore express this in terms of percentages. The most commonly used measures are indeed speed humps and cushions, raised intersections, gateway treatments, speed tables, chokers, chicanes, closures (diagonal, full), pavement narrowing. Roundabouts are widely applied in the Netherlands and they have built some 3000 of these in the past 10 years. As far as these traffic calming measures are concerned someone will encounter a number of these in virtually every town/city in the Netherlands.

3.2 Expected Results from Speed Humps-Manual Study

3.2.1 Speed and Volume Reduction Effect
Research has shown that properly designed and installed speed humps can reduce vehicle speeds to 15-20 mph (23.4-31.2 kph) when traversing speed humps and 25-30 mph (39-46.8 kph) in between properly spaced speed humps. Numerous studies have demonstrated that Watts’s humps can reduce speeds by about 8 mph in the vicinity of humps. Volumes are reduced, on the average, by about 18 percent. Because of its gentler profile, the Seminole County hump has a design speed of 25 to 30 mph at the hump, and approximately 35 mph in between humps. It has been shown to reduce speeds by about 6.5 mph and volumes by 12 percent. Some jurisdictions have found that speed of motorists at the hump and in-between the humps are not significantly different.

3.2.2 Speed vs. Ramp Dimensions
Ramp gradients can affect speeds - the steeper the gradient the larger the speed reducing affect. According to UK guideline gradients should not steeper than 1:10 and side gradients no steeper than 1:4. Ramp dimensions, slopes, and 85th percentile crossing speeds for three U.S. applications are presented in Table 2.

<table>
<thead>
<tr>
<th>U.S Cities</th>
<th>Applications</th>
<th>Dimensions</th>
<th>Ramp slopes</th>
<th>85th percentile crossing speeds</th>
</tr>
</thead>
<tbody>
<tr>
<td>Boulder, CO</td>
<td>speed tables</td>
<td>12' ramps</td>
<td>1:24</td>
<td>24 mph (39 kph)</td>
</tr>
<tr>
<td></td>
<td>raised crosswalks</td>
<td>22' plateau</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>6&quot; rise</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cambridge, MA</td>
<td>raised crosswalks</td>
<td>6' ramps</td>
<td>1:12</td>
<td>21 (34 kph)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>10' plateau</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>6&quot; rise</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gwinnett County, GA</td>
<td>speed tables</td>
<td>6' ramps</td>
<td>1:20</td>
<td>25 (40 kph)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>10' plateau</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>3-5/8&quot; rise</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

The only other source of speed data for trapezoidal tables comes from Denmark (see Table 3) applicable for 100mm height only. Clearly, desired crossing speeds depend on ramp slope and length, and plateau height and length. Table 3 shows that with the increase of ramp length and
slope, crossing speed over the hump also increases.

Table 3 Danish speed estimates for flat-topped measures of 100mm height (Delaware Department of Transportation, 2000)

<table>
<thead>
<tr>
<th>Ramp length in ft (m)</th>
<th>Ramp slope</th>
<th>Crossing speed in mph (kph)</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.3 (0.7)</td>
<td>1:7</td>
<td>12 (19)</td>
</tr>
<tr>
<td>2.6 (0.8)</td>
<td>1:8</td>
<td>16 (26)</td>
</tr>
<tr>
<td>3.3 (1)</td>
<td>1:10</td>
<td>19 (31)</td>
</tr>
<tr>
<td>4.3 (1.3)</td>
<td>1:13</td>
<td>22 (35)</td>
</tr>
<tr>
<td>5.6 (1.7)</td>
<td>1:17</td>
<td>25 (40)</td>
</tr>
<tr>
<td>6.6 (2.0)</td>
<td>1:20</td>
<td>28 (45)</td>
</tr>
<tr>
<td>8.2 (2.5)</td>
<td>1:25</td>
<td>31 (50)</td>
</tr>
</tbody>
</table>

3.3 Social Study
One of the reasons of installing traffic calming devices in residential areas is to make improvements to the environment such as reducing noise and air pollution caused by traffic.

3.3.1 Noise - Noise Effects of Sinusoidal Hump (Koganei, Japan)
Due to fewer and slower vehicles traffic calming can reduce noise in residential streets. An experiment was carried out by Design and Planning Traffic/Transport Laboratory Saitama University, Japan to examine the noise level of speed hump in residential area of Koganei, Tokyo, Japan. The hump had sinusoidal profile. The comparison was done for noise levels 20 days after hump installation and 5 days after hump removal for the sinusoidal speed hump. The noise level was measured for 5 minutes average. Only in two points the noise was at or above the permissible noise level of that area. In first point (time at 12:40) the noise was just on the value of limit it is may be due to the rush hour in the morning when lot of vehicles try to go fast. If we consider second point (14:30) it is may be due to unintentionally produced by the drivers, as the hump was new in that location. The experiment was done for 90% confidence level. The overall noise of that area due to sinusoidal hump was acceptable.

3.3.2 Vibration - Vibration Effects of Sinusoidal Hump (Koganei, Japan)
An experiment was carried out by Design and Planning Traffic/Transport Laboratory Saitama University, Japan to examine the vibration level of speed hump. The hump was located in residential area of Koganei, Tokyo, Japan. The comparison was done for vibration levels 2 days before hump installation, 20 days after hump installation and 5 days after hump removal for the sinusoidal speed hump. The vibration level was measured for 5 minutes average. For all cases the vibration level was below the permissible level (65dB). The experiment was done for 90% confidence level. So the overall vibration of that area due to sinusoidal hump was acceptable.

4. SPEED HUMPS
The most effective traffic calming measures to lower vehicle speeds are vertical deflectors, commonly known as road humps. Variations of the standard road humps are known as speed tables and speed cushions or speed lumps. Since speed hump is the most widely used device, different features of hump are emphasized here.

4.1 Past Researches on the Effects of Speed Humps
Speed humps in Montgomery County, Maryland, typically reduced 85th percentile speeds by 4 to 7 mph. The installation of the hump reduced accident frequency. The humps did not have a
consistent effect on traffic volumes, though (Huang and Cynecki, 2000; Loughery and Katzman, 1998).

Five speed humps were built along a half-mile stretch of Grey Rock Road in Agoura Hills, California. Instead of the usual 3 in (inch), these humps were 2.75 in high. The 85th percentile traffic speeds fell by 6 to 9 mph after the humps were installed. Traffic volumes remained constant and motorists did not divert to other residential streets (Huang and Cynecki, 2001; Cline, 1993).

In three Australian cities, Corio and Croydon in Victoria and Stirling in Western Australia, the 85th percentile speeds at speed humps dropped by half or more after installation. Mid-hump speeds fell by about one-fourth to one-third. Daily traffic volumes fell by one-fourth to roughly one-half (Huang and Cynecki, 2001; Hawley et al., 1992; McDonald and Jarvis, 1981; Richardson and Jarvis, 1981).

4.2 Guidelines for Speed Hump Installation-Case Study
Traffic calming measures are self-enforcing physical features which effectively change the design speed. The design of traffic calming measures should be undertaken by due precision and engineering judgment of the designer.

4.2.1 Case Study for Santa Ana, California, USA:
Conditions for street geometry and physical characteristics that are followed for hump installation in Santa Ana are:
- Street is a residential street with no more than one lane in each direction.
- Street is neither a primary fire access route nor a transit route.
- The street is a through street, at least 500 feet long and uninterrupted by stop sign or traffic signal.
- The posted or prima facie speed limit is 25 mph.
- The 85th percentile speed is > 35 mph.
- Adequate visibility can be provided at all speed hump locations.
- Daily traffic on the street segment is less than or equal to 3500 vehicles per day.

4.2.2 Case Study for Ku-ring-gai Traffic Committee, Australia:
Conditions of hump applications for Ku-ring-gai Traffic Committee, Australia (Ku-ring-gai Traffic Committee-19 September 2002) are:
- Where vehicle speeds on a local street are high
- Where traffic volume is low to medium <5000 vpd
- Where accident numbers are high
- Where it can be constructed at right angles to the traveled path
- Where it is clearly visible to approaching motorists
- To maintain a 40km/hr mean speed along a street length
- Devices should be implemented at a minimum of 150m interval
- Should not be implemented in isolation.

4.3 Different Hump Profiles Currently in Use
Designs vary throughout different countries but the basic road hump can be parabolic, sinusoidal, flat-topped, and round or circular in shape. Flat-topped speed humps are called speed tables, raised crosswalk or pedestrian crossings. The standard or Watts profile hump, developed and tested by Britain's Transport and Road Research Laboratory, is the most common speed control measures in the United States. The hump to be parabolic shape, 12 feet
(3.67m) long, with a height of three to four inches (76-100mm) and has an 85th percentile speed (design speed) of 15 to 20 mph (23.4-31.2kph). 14-foot parabolic speed hump is a modified version of Watts profile having 85th percentile speed 3 mph higher than the standard 12-foot Watts hump (Ewing, 1999). Another commonly used design shape in the U.S.A is that of the Seminole County speed hump which is flat-topped speed hump of 22 feet in length, and 3 to 4 inches high with 6-foot ramps at the ends and a 10 foot field on top having a 85th percentile speed of 25 to 30 mph. Following figures show typical speed table design.

![Figure 1 Speed table](image1) ![Figure 2 Raised crosswalk](image2)

The recent application of road hump used in residential areas in the UK with an enforced speed limit of 20 mph (32km/h). The standard road hump has a circular cross-section with a chord length (in direction of travel) of 3.7 m and a height of 50 mm (minimum) to 100mm (maximum) and is greater than 900 mm long.

Canadian Guide to Traffic Calming (Transportation Association of Canada, 1998) recommends all speed humps in Canada to be sinusoidal in shape rather than the parabolic shapes. Figure 3 shows cross-section for properly designed speed humps. There is a recommended design for collector streets and for local streets. The speed hump for the collector street is 80 mm (3in) high and 7.0 meters (23ft) wide at the base and has a flat centre section. This flat section makes it easier for larger vehicle such as buses and fire vehicles to traverse. The speed hump design for local roads is also 80 mm (3in) high but is only 4.0 meters (13ft) wide at the base and does not have a flat centre section.

![Figure 3 Speed hump design for collector street (TAC, 1998)](image3)

**4.4 Speed Versus Spacing of Slow Points**

Drivers accelerate between slow points. To counter this tendency and limit midpoint speeds, many U.S. jurisdictions have established guidelines for the spacing of slow points. Prescribed spacing is typically in the range of 300 to 500 feet (90 to 150 m). Instead of applying fixed guidelines, the MOA (Municipality of anchorage Traffic Department, Alaska) will compute required spacing based on target speeds. Ordinarily, midpoint speeds will be allowed to climb no more than 5 mph above the posted speed limit. Crossing speeds at slow points will be no
more than 5 miles per hour (mph) below the posted speed limit. The speed differential on a given stretch of roadway is thus limited to 10 mph in the interest of traffic safety, noise control, fuel conservation, and driver acceptance. This maximum speed, along with the crossing speed at slow points and the comfortable travel speed on the street itself (between slow points), determines the required spacing of slow points. As spacing increases to 600 feet (183 m) between slow points, midpoint speeds rise to 90 percent of their maximum value. The maximum value, however, a speed between the pre-existing speed and the 85th percentile speed at the slow points.

4.5 Spacing of Slow Points
The number and spacing of speed humps/tables often depend on the implementing authority and project goal. For example, Gwinnett County, Georgia specifies a spacing of 350 to 500 feet with a series of speed humps extending no more than 0.75 mile (Urban et al., 1999). Figure 4 shows the spacing of hump for different regions (Source: Questionnaire survey and Traffic calming manual of individual region).

A series of speed humps/tables are often more effective in reducing speeds than single installations since it prevents a vehicle from speeding up after negotiating a single device (ITE Traffic Engineering Council, 1997). Table 4 summarizes some of the speed hump/table spacing and design dimensions used in the United States, Canada and England.
Table 4 Spacing values currently used in speed hump installations (Collected from manual of individual regions)

<table>
<thead>
<tr>
<th>Region</th>
<th>Design/Dimension</th>
<th>Hump length (feet (m))</th>
<th>Shape</th>
<th>Midpoint ht, inch (mm)</th>
<th>Ramps, ft (m)</th>
<th>Platue, ft (m)</th>
<th>Spacing, ft (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>ITE</td>
<td></td>
<td>16 parabolic</td>
<td>3-4</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>22 parabolic</td>
<td>3-4</td>
<td></td>
<td>6</td>
<td>10</td>
<td></td>
</tr>
<tr>
<td>Belmont, CA</td>
<td></td>
<td>12 (3.66m) parabolic</td>
<td>3</td>
<td></td>
<td></td>
<td></td>
<td>275</td>
</tr>
<tr>
<td>Concord, NH</td>
<td></td>
<td>14 parabolic</td>
<td>3</td>
<td></td>
<td></td>
<td></td>
<td>300 to 600</td>
</tr>
<tr>
<td>Montgomery, MD</td>
<td></td>
<td>12 parabolic</td>
<td>3</td>
<td></td>
<td></td>
<td></td>
<td>500-750</td>
</tr>
<tr>
<td></td>
<td></td>
<td>22 parabolic</td>
<td>3</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Texas</td>
<td></td>
<td>12 parabolic</td>
<td>3-4</td>
<td></td>
<td>6</td>
<td>10</td>
<td>200 to 600</td>
</tr>
<tr>
<td></td>
<td></td>
<td>22 parabolic</td>
<td>3</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pennsylvania</td>
<td></td>
<td>12 parabolic</td>
<td>3-4</td>
<td></td>
<td>6</td>
<td>10</td>
<td>300 to 600</td>
</tr>
<tr>
<td></td>
<td></td>
<td>22 parabolic</td>
<td>3</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Santa Ana, CA</td>
<td></td>
<td>12 parabolic</td>
<td>2.62</td>
<td></td>
<td></td>
<td></td>
<td>400-600</td>
</tr>
<tr>
<td>Bowling Green, KY</td>
<td></td>
<td>13 sinusoidal</td>
<td>3.2</td>
<td></td>
<td></td>
<td></td>
<td>300-500</td>
</tr>
<tr>
<td></td>
<td></td>
<td>23 sinusoidal</td>
<td>3.2</td>
<td></td>
<td>6.5</td>
<td>10</td>
<td></td>
</tr>
<tr>
<td>Sacramento, CA</td>
<td></td>
<td>12 parabolic</td>
<td>3.25 - 3.75</td>
<td></td>
<td></td>
<td></td>
<td>250-600</td>
</tr>
<tr>
<td></td>
<td></td>
<td>22 parabolic</td>
<td>3.25 - 3.75</td>
<td></td>
<td>6</td>
<td>10</td>
<td></td>
</tr>
<tr>
<td>Dover, DL</td>
<td></td>
<td>14 (4.2m) parabolic</td>
<td>3 (75mm)</td>
<td></td>
<td></td>
<td></td>
<td>300-500 (90-150m)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>22 (6.7m) parabolic</td>
<td>3 (75mm)</td>
<td></td>
<td>6 (1.8m)</td>
<td>10 (3m)</td>
<td></td>
</tr>
<tr>
<td>Hot Springs, AS</td>
<td></td>
<td>12 parabolic</td>
<td>3-3.5</td>
<td></td>
<td></td>
<td></td>
<td>200-400</td>
</tr>
<tr>
<td>Sandusky, OH</td>
<td></td>
<td>12 parabolic</td>
<td>3-4</td>
<td></td>
<td></td>
<td></td>
<td>250-300</td>
</tr>
<tr>
<td>Portland, OR</td>
<td></td>
<td>14 parabolic</td>
<td>3</td>
<td></td>
<td>6</td>
<td>10</td>
<td>300-600</td>
</tr>
<tr>
<td></td>
<td></td>
<td>22 parabolic</td>
<td>3</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Tulsa, OK</td>
<td></td>
<td>14 parabolic</td>
<td>3-4</td>
<td></td>
<td>6</td>
<td>10</td>
<td>300-500</td>
</tr>
<tr>
<td></td>
<td></td>
<td>22 parabolic</td>
<td>3-4</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Salt Lake city, UT</td>
<td></td>
<td>7 parabolic</td>
<td>3-4</td>
<td></td>
<td></td>
<td></td>
<td>300-500</td>
</tr>
<tr>
<td></td>
<td></td>
<td>22 parabolic</td>
<td>3-4</td>
<td></td>
<td>7</td>
<td>8</td>
<td></td>
</tr>
<tr>
<td>Canadian Guide</td>
<td></td>
<td>13.12 (4m) sinusoidal</td>
<td>2.62 (80mm)</td>
<td></td>
<td></td>
<td></td>
<td>197-410 (60-125m)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>22.96 (7m) sinusoidal</td>
<td>2.62 (81mm)</td>
<td></td>
<td>6.56 (2m)</td>
<td>9.84 (3m)</td>
<td></td>
</tr>
<tr>
<td>Larch street, Canada</td>
<td></td>
<td>12-14 (3.7-4.3m) sinusoidal</td>
<td>2.46 (75mm)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vancouver, Canada</td>
<td></td>
<td>12 (3.7m) sinusoidal</td>
<td>3 (76mm)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>22 (6.7 m) sinusoidal</td>
<td>3 (76mm)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Saanich, Canada</td>
<td></td>
<td>15 parabolic</td>
<td>3-5</td>
<td></td>
<td>6</td>
<td>10</td>
<td>300-500</td>
</tr>
<tr>
<td></td>
<td></td>
<td>23 parabolic</td>
<td>3-5</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hampshire, England</td>
<td></td>
<td>12 (3.7m) circular</td>
<td>1.97-3.93 (50-100mm)</td>
<td></td>
<td></td>
<td></td>
<td>65.6-590 (20-180m)</td>
</tr>
</tbody>
</table>

() indicates transformed data

4.6 Selection of Spacing
Research has revealed that road hump spacing has the greatest power upon average vehicle
speeds along a link. Once design speeds are chosen, traffic calming measures and spacing appropriate to design speeds can be selected. Results from UK experiments are shown in Table 5, which compares before speed with after speed for different hump spacing. Speeds across 75mm high round-top humps averaged 14.7 mph; 13.8 mph for 100 mm high humps. Speeds across flat-top humps averaged 12.8 mph at a height of 75 mm and 13.6 at a height of 100 mm.

<table>
<thead>
<tr>
<th>Hump Spacing (m)</th>
<th>20</th>
<th>40</th>
<th>60</th>
<th>80</th>
<th>100</th>
<th>120</th>
<th>140</th>
</tr>
</thead>
<tbody>
<tr>
<td>20 mph</td>
<td>13</td>
<td>14</td>
<td>15</td>
<td>16</td>
<td>18</td>
<td>19</td>
<td>20</td>
</tr>
<tr>
<td>25 mph</td>
<td>15</td>
<td>16</td>
<td>17</td>
<td>18</td>
<td>20</td>
<td>21</td>
<td>22</td>
</tr>
<tr>
<td>30 mph</td>
<td>17</td>
<td>18</td>
<td>19</td>
<td>20</td>
<td>22</td>
<td>23</td>
<td>24</td>
</tr>
<tr>
<td>35 mph</td>
<td>19</td>
<td>20</td>
<td>21</td>
<td>22</td>
<td>24</td>
<td>25</td>
<td>26</td>
</tr>
</tbody>
</table>

Danish guidelines consider the traffic volume and functional class of a roadway. The Danes consider 6.5-meter humps suitable for 40-kph (25 mph) applications. For 50-kph (31 mph) applications, the length of circular humps in Denmark is 9.5 meters (31 feet). The Danes provide guidance for spacing of slow points (see Table 6). For 40-kph (25 mph) midpoint speeds, slow points are typically spaced no more than 100 meters apart (roughly 325 feet). For 50-kph (31 mph) midpoint speeds, the spacing increases to 150 meters (500 feet).

<table>
<thead>
<tr>
<th>Desired Speed (kph)</th>
<th>Distance Between Slow Points (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>50</td>
<td>150</td>
</tr>
<tr>
<td>40</td>
<td>100</td>
</tr>
<tr>
<td>30</td>
<td>75</td>
</tr>
<tr>
<td>10-20</td>
<td>25 (maximum 50)</td>
</tr>
</tbody>
</table>

kph = kilometers per hour; m = meters

Canadian practice (Canadian Guide to Neighborhood Traffic Calming, 1998) to achieve desired 85th percentile speed is shown in Table 7: Design and Planning Laboratory of Saitama University carried out an experiment for selection of hump spacing to achieve desired 85th percentile speed, shown in Table 8.

<table>
<thead>
<tr>
<th>Desired 85th percentile speed (kph)</th>
<th>Hump Spacing (m)</th>
</tr>
</thead>
<tbody>
<tr>
<td>50</td>
<td>Every 125m</td>
</tr>
<tr>
<td>45</td>
<td>Every 100m</td>
</tr>
<tr>
<td>40</td>
<td>Every 80 m</td>
</tr>
<tr>
<td>30</td>
<td>In pairs 4 m to 122 m apart, every 60 m</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Hump Spacing (m)</th>
<th>85th percentile Speed (kph)</th>
</tr>
</thead>
<tbody>
<tr>
<td>40</td>
<td>30</td>
</tr>
<tr>
<td>56</td>
<td>31</td>
</tr>
</tbody>
</table>

Table 5 Effect of road humps spacing on vehicle speed

Table 6 Spacing of slow points in Denmark for different desired speeds

Table 7 Spacing of humps for desired 85th percentile speeds in Canada (TAC, 1998)

Table 8 Spacing of humps for desired 85th percentile speeds
5. EFFECTIVENESS OF SPEED HUMPS

Traffic speed and volumes are reduced due to traffic calming in almost every case. Due to reduced speed they can reduce severity of accidents also. One study was performed by the City of Portland evaluating over 500 speed humps and is reported in City of Portland Speed Bump Peer Review (Kittleson and Associates, 1998). Following conclusions were obtained:

5.1 Traffic Speeds
✧ On average, speed humps reduced 85th percentile travel speeds by about 7 mph after speed humps were installed. Average speed over the speed humps was about 25 mph.
✧ Overall, approximately 13% of motorists traveled more than 10 mph over the speed limit before installation of speed humps compared to 2% afterwards
✧ The study revealed that residents’ perceptions about speed hump impacts on speed were consistent with the documented speed impacts.

5.2 Traffic Volumes
✧ On streets treated with speed humps (14-foot), the average traffic volume reduction was 33%. After installing longer speed humps (22-foot), traffic volumes decreased by an average of 21%.
✧ On average, parallel untreated streets experienced slight increases in traffic volume (about 4%).
✧ The results of the public opinion survey showed that 64% of the respondents who lived on streets treated with speed humps perceived a reduction in traffic volumes.

5.3 Vehicle Crashes
✧ With installation of speed humps, the incidence of crashes on treated streets decreased an average of 39%.
✧ The crash rate (annual crashes per average daily traffic (ADT)) decreased on treated streets an average of 5% after speed humps were installed.

A recent survey of 35 British calming schemes, with the majority including vertical shifts in the carriageway, found that the average reduction in the 85th percentile speed was 16kph (10mph).

5.4 Residents’ Opinion
A public opinion survey was distributed to approximately 1,200 residents living on or parallel to a speed bump street. 400 people responded. In general, more respondents thought speed bumps improved livability in their neighborhood (48%) than thought the livability got worse (39%). Of those living on streets treated with speed bumps, 57 percent of the respondents believed that speed bumps have improved livability on their street. Of those living on parallel untreated streets, 28 percent of respondents believed that speed bumps improved livability on their street and 44 percent thought that livability has gotten worse as a result of speed bumps.

6. DISCUSSION

The effectiveness of a traffic calming device mostly depends on the spacing of the devices. The maximum acceptable operating speed for the area should be determined. The design
speed is determined by the dimensions of the traffic calming device. It should be assured that noise and vibration do not become an annoyance to the residents.

From the study it can be seen that hump spacing varies between 61-183m (200-600 ft) in USA, 25-150m in Denmark, 20-180m in England, and 91-152m in Canada. UK practice is for hump spacing not to be more than 180m or less than 20 m apart, and the first in the series must be 40m or less from a low-speed feature such as an intersection or bend. With the increase of desired crossing speed, distance between slow points also increases, which is also observed from the research that. The effectiveness of flat-topped speed humps (or speed tables, raised crosswalk or pedestrian crossings) depends on the rise, the slope of the ramp and the distance between adjacent humps. Speed tables give higher design speed than speed humps due to their flat fields plus ramps that are more gently sloped than speed humps.

From the above comparative study of traffic calming designs it is clear that speed humps are designed for residential roads that have two lanes or less at a posted speed limit of 30 mph (47kph) or less, and 85th percentile speeds of 31-34 mph (48-53kph). Local roadways that carry traffic volumes of 600-5000 vehicles per day are good candidates. Speed humps do not typically impact locations where traffic volumes less than 600. Speed humps will not have a significant positive effect on roads with traffic volumes greater than 5000 vehicles per day. Roads with high volumes need other traffic control devices to alleviate problems.

Hump shape varies in different regions such as USA installs parabolic hump in almost every cases whereas Canada uses sinusoidal hump and in case of England it is circular in shape. Sinusoidal hump is expensive as it is difficult to construct. Sinusoidal humps are more comfortable for ride because of its initial rise is slower. Snow clearance may also be facilitated by the sinusoidal profile.

Before a City decides to pursue traffic calming options, it is important that the impacts of all levels of traffic calming be carefully considered. In most instances, the benefits are quite apparent and estimated, while the limitations can be much more unexpected. Greater emphasis should be given on the potential problems so that judgment can be made in a more fully well informed manner. Each city that wants to install traffic calming device should define the speed and volume level for which a device may be considered to install.

In communities where traffic calming is being tried for the first time, it may be useful to lay out temporary markings to test it. Decision should be made after the measure has been monitored and evaluated regarding its effectiveness in solving the identified traffic problem. After installation, monitoring and evaluation of a traffic calming measure, a follow-up traffic study may be conducted to evaluate residents’ and motorists’ reactions by sight observations, traffic speed and volume surveys. The analyses of the data collected should determine whether the measure or solution has met its desired objective. If the measure does not meet the objective, then question comes about removal of the device. The removal or modification should also be based on analyses conducted after installation, that is, during the monitoring and evaluation stage.

In order to assess the effects of traffic calming device monitoring should be done before traffic calming starts and also at certain intervals after the installation of the device. There may be chance that first few traffic calming projects implemented in a community tend to be the most controversial. Public support generally increases as residents become more familiar with traffic calming and its impacts. From this research, it is clear that residents’ participation
is essential for an effective traffic calming program.

7. CONCLUDING REMARKS

The level of success of a traffic calming exercise can be determined on the basis of continued monitoring of certain indicators, for example speed, traffic flow, noise levels, accident rates, and the effect of residents’ satisfactions. In order to measure the success of the project, data collection of some parameters such as traffic speed, volume and safety issues should be done before traffic calming starts. After a certain period improvement targets over a given time frame can be determined for these indicators. From the examples of traffic calming guidelines in cities outlined above (and others not mentioned here), it is clear that for an effective implementation of a traffic calming program, guiding principles are needed to make neighborhoods more livable.

The use of vertical restrictions such as humps will effectively slow motorists, but if a series of humps are placed too far apart, motorists will accelerate once they have crossed over the hump thus increasing road noise. The factor that may have the greatest impact on the effectiveness of a speed hump/table installation is the spacing of the slow points. The maximum acceptable operating speed for the area should be determined. The impact or design speed of the speed hump/table and the typical operational capabilities of the vehicles in the traffic flow may help determine the spacing of the devices (Ewing, 1999).

Acceptance of road humps schemes depends in part on whether traffic speeds are reduced. However, it is also influenced by the degree of discomfort to vehicle occupants, and the effect the road humps may have on traffic noise and ground-borne vibrations. Residents of streets where road humps are installed will wish to be assured that any traffic noise or ground-borne vibrations generated are not going to amount to a nuisance. There are several means, which can reduce noise as the selection of road surface material, smaller number of vehicles and slower vehicles. But it is important that motor vehicles travel at a steady speed rather than run fast and break near the traffic calming device.

REFERENCES


Richardson, E., and Jarvis, J. R. (1981) The Use of Road Humps on Residential Streets in the City of Stirling, ARRB (Australian Road Research Board) Internal Report, AIR 335–3, Western Australia.
