Traffic Calming of State Highways: Application New England

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16. Abstract

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This study has two main objectives; to evaluate the effect on safety of traffic calming of arterials and to look at the acceptance of traffic-calming measures. We found that there are only a few truly traffic-calmed arterials worldwide, and even fewer ones that have been evaluated. In North America, most traffic calming of arterials has occurred as a byproduct of mobility improvements, such as reducing roads from four lanes to three lanes with center turn lanes and constructing roundabouts. Stevens Avenue in Portland is an exception to that. The overall effectiveness of that project and other arterial traffic-calming schemes has been moderate even if there is a clear reduction in pedestrian injuries. The study of the general public's and city officials' acceptance of traffic-calming devices showed that humps and other vertical devices are less accepted than narrowed roadways and horizontal realignments. Given the public resistance to traffic calming of major arteries, the conclusion is that speed control through other means may, in the long run, be preferable to construction of humps and chokers on arterials. The public is in general in favor of having "other people" comply with laws and regulations, including speed limits, but most people do not themselves voluntarily act according to such principles when it comes to speeding. Enforcement and public campaigns have some possibilities of achieving speed compliance but the authors' findings suggest that electronic, in-vehicle speed governors assuring legal speeds may be the most effective way of achieving speed compliance. This would probably result in fewer negative side effects than reconstruction of roadways.

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1 INTRODUCTION

Many small towns in New England have their town centers located along rural highways. These highways are often classified as major collectors or arterials, meaning that the agency with jurisdiction over the road considers mobility (serving through traffic) to be a higher priority than accessibility (providing local access). Regardless of the classification of the roads passing through them, roads through town centers often see a great deal of pedestrian activity as well as parking and turning maneuvers. Because it is difficult to maintain safety under such conditions, especially at high vehicular travel speeds, posted speed limits are frequently reduced to 25 or 30 mph (40 or 48 km/h) on a highway posted at 45 to 55 mph (70 to 88 km/h) outside the town center. It is also generally understood that many drivers do not respect these reduced speed limits, either because they do not acknowledge the need to slow down or they miss the signs altogether. It does not help that frequently there has been little change in the geometric cross section between the section posted at 55 mph (88 km/h) and the one posted at a lower speed. But speed is important. According to statistical data from FHWA (U.S. Department of Transportation July 2001), almost one of every three traffic fatalities is related to speeding. This will be further discussed in the next chapter.

Over the past decade there has been growing interest in the United States to implement traffic calming. Traffic calming is typically achieved by changing the physical geometry of a road section to influence drivers' choice of speed. But lower speeds can also be achieved through education, enforcement or the mounting of speed limiters in vehicles. So far, physical traffic calming in the U.S. has been limited to local roads and minor collectors. In Europe, it is more common to try to use similar techniques to reduce speeds and traffic volumes on arterials as well. In-vehicle speed limiters are also used on an experimental basis in several European countries but so far not at all in North America.

This report explores possibilities for implementing traffic-calming devices on major and minor arterial routes through built-up areas of rural towns. First, in Chapter 2 we address the issue of speed limit non-compliance and its effect on safety. Then in Chapter 3 we look at overall highway fatality risk in the U.S. and compare it to other common risk scenarios. Chapter 4 gives a brief history of traffic calming throughout the world. Chapter 5 discusses possible ways of implementing traffic calming on arterials, including legal and social issues relating to it. Chapters 6 and 7 describe experience with traffic calming in Europe and North America respectively. Chapter 8 describes and reports results from several surveys of public and town official opinions and experience with traffic calming, especially focusing on levels of comfort and behavioral responses to installation of traffic-calming devices. Finally, Chapter 9 gives the final conclusions of the study.

2 SPEED

2.1 Compliance

The lack of respect for posted speed limits appears to translate into high multi-vehicle crash rates on posted "low-speed sections" of highways. (Ossenbruggen *et al.* 2001) An analysis of actual speeds on Mt. Hope Avenue, a two-lane collector road on the outskirts of the densely developed area of Bangor, Maine, shows that less than 5% of motorists travel at or below the speed limit of 25 mph (40 km/h). The measurements, taken around noon on a September weekday in 1999, show that more than half of the motorists exceeded the speed limit by more than 10 mph (16 km/h) and that, on average, there were about two cars a minute traveling more than 15 mph (24 km/h) above the posted limit. (Ordway, 1999) Speeds during commuting hours may be even higher. Furthermore, a radar gun was used to measure speeds, which may have introduced a bias towards under-estimating the speed distribution, since some drivers likely slowed down once they realized their speed was being monitored. These measurements translate into almost a million cars each year traveling on this road more than 15 mph (24 km/h) over the speed limit, assuming these observations to be typical for daytime traveling. It is noteworthy that this street is among the ten in Bangor with the most speeding tickets issued, and it is one of the streets patrolled most regularly by the police. Even so, only 17 speeding tickets were issued here in 1998, representing roughly one in 50,000 drivers exceeding the speed limit by more than 15 mph (24 km/h). For drivers exceeding the speed limit by less than 15 mph (24 km/h), the chance of being fined is negligible. Unfortunately, measurements from seventeen other locations in Bangor show that this situation is not unique, nor even the worst. At one location, less than 1% of drivers complied with the speed limit when passing a playground/public pool area. This lack of respect for local speed limits is observed all around New England. For example, for the highway through Troy, New Hampshire, "average vehicle speeds are 16 kph (10 mph) or higher than posted speeds as one approaches the Town Center from the north and south, and as one departs the Town Center traveling north on NH 12." (VHB, 1999)

Most likely, enforcement would by itself have to be intensified greatly and carried out at many more locations than today to have any serious impact on the problem.

2.2 Effect on Safety

The prevalence of speeding clearly shows that implementing reduced speed zones without aggressively enforcing them is often not effective for reducing vehicle speeds to safe levels. However, physical measures may be a more effective alternative than enforcement. But before discussing how to reduce speeds, let's look at what constitutes a 'safe' speed? Would 25 mph (40 km/h) be a safe speed on a collector or arterial in an area with significant pedestrian activity? The answer to this depends on many factors, such as the frequency and intensity of pedestrian crossing activity, street widths, sight distances, and the standard selected for public safety. More and more nations are setting goals to drastically reduce or even eliminate fatal and incapacitating highway crashes. NHTSA and NTSB both acknowledge that high speeds contribute to serious injuries and fatalities, but speed reduction in compact areas is not listed as a top priority for these agencies. However, the Insurance Institute for Highway Safety acknowledges speeding to be a premier safety problem (See http://www.hwysafety. org/safety_facts

/qanda/speed_limits.htm). Also, a survey conducted by one of the authors of this report, where the participants were chosen by Dr. Frank Haight, editor-in-chief of Accident Analysis and Prevention and other transportation journals, polled seventeen European experts considered most knowledgeable about factors contributing to highway injuries and fatalities. These experts overwhelmingly agreed that “too high speeds” is the number one issue to be addressed, well ahead of “alcohol and drugs,” “elderly driver issues,” or “young driver issues.” (Gårder and Leden 1998)

The influence of speed—as approximated by speed limit—on pedestrian safety can be illustrated by data from Maine as seen in Figure 1. The data covers the years 1994-98, with a total of 1589 reported pedestrian crashes.

However, actual speeds vary quite a bit even where the speed limit is the same. The effect of actual speed is illustrated by Table 1. The speed limit at all locations included here is 25 mph (40 km/h). The table shows a comparison between actual numbers of pedestrian crashes observed at the randomly chosen locations (in Maine) and the number of crashes predicted by two models that use vehicle volumes and pedestrian volumes as the only prediction variables. The locations are divided into low, medium and high-speed. The low-speed locations have average daytime speeds below 20 mph (32 km/h), medium-speed locations have average speeds in the 20 to 25 mph (32-40 km/h) interval, and high-speed locations have average speeds above 25 mph (40 km/h).

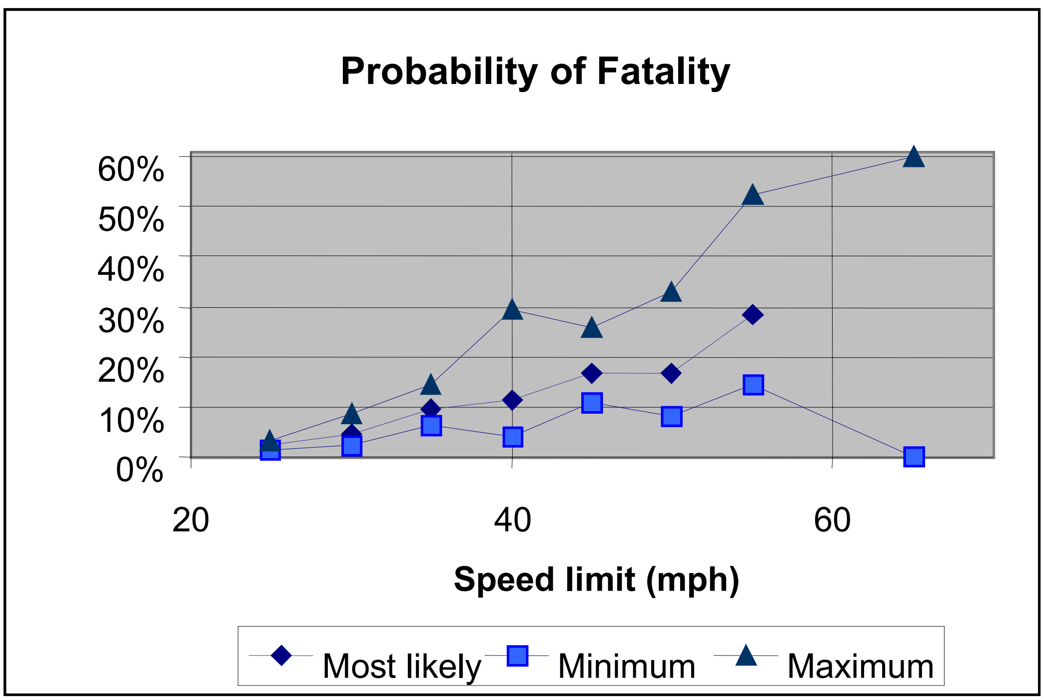


Figure 1 Speed limit and probability of fatality with 95% level of confidence

Table 1 Predicted and observed pedestrian crashes by typical speed, street width and control

	Speed	2-lane streets		>2-lanes	
		Average number predicted by the VTI model and the TRL model for five years	Observed number of crashes in five years	Average number predicted by the VTI model and the TRL model for five years	Observed number of crashes in five years
Unmarked location	low	2.63	0	0.00	0
	medium	0.08	1	2.21	9
	high	0.65	2	0.21	5
Marked crosswalk, no signal, no barrel	low	5.43	3	0.20	0
	medium	0.00	0	2.29	6
	high	1.04	1	0.53	5
Marked crosswalk, no signal, with barrel	low	1.76	1	1.11	0
	medium	0.00	0	0.00	0
	high	0.00	0	0.00	0
Marked crosswalk, signal	low	0.00	0	1.52	3
	medium	0.25	1	0.93	1
	high	0.22	0	0.11	1

Statistically significant deviances were found for a few layouts in the table. Clearly more dangerous than expected (predicted) are the wide, high-speed, unmarked locations (p=0.000003) and the wide, medium-speed, unmarked locations (p=0.0005). Also more dangerous are high-speed, marked, wide locations (p=0.0002) and medium-speed, wide, marked locations (p=0.03).

Not statistically significant deviances were found for several layouts. Somewhat more dangerous than expected are medium-speed unmarked narrow streets (p=0.08) and high-speed unmarked narrow streets (p=0.14). The low-speed unmarked locations are safer than expected (p=0.07).

None of the signalized observations deviate from the predicted effect in a statistically significant way. However, the low-speed signalized locations are somewhat more dangerous than expected whereas the non-signalized low-speed locations are safer than expected (p=0.014). There was not a single pedestrian crash in an unmarked, non-signalized, low-speed location in spite of very high pedestrian activity at many of them.

3 OVERALL NATIONAL SAFETY LEVELS

People expose themselves to risks in traffic that are greater than in any other risk area. Ossenbruggen (1998) has championed the idea that the average risk of dying in a traffic accident should be no more than one in one thousand over a lifetime, a similar risk as that which is accepted in some other Public Health areas. Today, the risk in the United States of being killed in a highway-related crash is about one in 90. The roadway systems are substantially safer in several European countries than in the United States. For example, the Swedish fatality rate is around 6 people killed per year per 100,000 population. In the United States, that rate is around 16 (US DOT 2001). The difference is less pronounced, but still in Sweden's favor if the rate is calculated as fatalities per distance driven (by motor vehicles), 1.10 per 10^8 km (1.76 per 10^8 miles) in the U.S. compared to 0.90 per 10^8 km (1.45 per 10^8 miles) in Sweden. (FHWA 1996) This is in spite of the fact that many more people bicycle and walk on the roadways in Europe than in the United States. If we isolate the safety of unprotected road users, the fatality rate per 10^8 miles walked is about 60 in the United States (37 per 10^8 kilometers), compared to 6.1 (3.8) in Sweden. (Rates are based on official statistics.) There is a similar difference for bicyclist fatalities per mile ridden: 24 per 10^8 miles (15 per 10^8 km) in the United States and 5.8 per 10^8 miles (3.6 per 10^8 km) in Sweden. Can't the United States do better?

We believe that the United States can do better. Part of the solution may be found in lowering vehicular speeds in built-up areas. One of the main principles of the Swedish Vision Zero states, "The level of violence that the human body can tolerate without being killed or seriously injured shall be the basic parameter in the design of the road transport system." Vision Zero's long-term objective is to eliminate all fatalities and incapacitating injuries. The goal was adopted by the Swedish Parliament in June 1993. An intermediate goal was 400 fatalities for the year 2000. The actual number of fatalities in 200 was around 500, down from over 1,300 at its peak in the mid 1960's. This program suggests the following hierarchical division of roads and streets as part of how to accomplish this:

- Through traffic routes with a speed limit of 70 km/h (44 mph) or more should have only grade-separated pedestrian crossings;
- 50 km/h (31 mph) urban arterials should have actual speeds reduced to less than 30 km/h (19 mph) at every pedestrian and bicycle crossing, and to 40 to 50 km/h (25 to 31 mph) elsewhere;
- Residential local streets should never allow [actual] speeds greater than 30 km/h (19 mph);
- Traffic-calmed streets planned for walking speed (Woonerven, see page 12) should be promoted;
- Car-free areas are to be encouraged.

There are obviously many potential ways of improving pedestrian safety. One such alternative is traffic calming. Over the last twenty years, the safety of pedestrians has already been improved significantly in the United States, but only if we measure safety as in public health, in deaths per 100,000 population. The major reason for the improvement seems to be a reduction in miles walked rather than a safer pedestrian environment. To restrict people, especially children and older citizens, from using our streets is not the optimal way of achieving safety. Rather, encouraging people to walk and ride bikes rather than drive cars has health benefits, which in Europe are estimated to be substantially larger than the negative effects of crashes. The French researcher Carré (1998) estimates that an hour of life expectancy is gained for every hour a person is engaged in moderate exercise (such as walking). However, the average pedestrian in the United States will have to walk 7-days a week, 24-hours a day, for 63 years before having a statistical risk equal to one of being fatally injured in a pedestrian crash. This has been calculated using the U.S. fatality rate of 60 per 10^8 miles walked and assuming people walk with a velocity of 3 miles per hour, which means that a person, on average, will have to walk 555,000 hours (63 years) before being fatally injured. In other words, in the U.S., a pedestrian walking "all his life" for an hour a day, would after 70 years statistically have gained approximately 3 extra years of life expectancy [(70)(1)/24 = 2.9] but he would also statistically have a risk of 4.6% [(70)(365)(1) /555000)=0.046] of having been killed in a pedestrian crash before that. Assuming that the chance of a fatal crash remains constant over the 70 years, the lost number of years *if* killed would be 35. And, the expected lost number of years when reaching the age of 70 would be 0.046 x 35 = 1.6 years. In other words, a pedestrian walking an hour will according to these assumptions gain an hour of expected life (health benefits) but will lose about half of that (in crash risk). That is too high a gamble, we think, and a conclusion would be that walking today is too dangerous in this country, and we need to lower the risk to levels similar to those currently experienced in, for example, Sweden.

4 HISTORY OF TRAFFIC CALMING

Regulations ensuring low vehicular speeds have a long history. The "Red Flag Act" was passed in England in 1865 and not repealed until 1896. (Red Flag Act 2002) It restricted the speed of horse-less vehicles to 4 mph in open country and 2 mph in towns. The act required three drivers for each vehicle—two to travel in the vehicle and one to walk ahead carrying a red flag. Similar laws were enacted in many U.S. States and kept into the 20th century in, for example, Connecticut, though the urban speed limit varied between different jurisdictions and was typically 5, 10 or 12 mph (8, 16 or 19 km/h).

4.1 The Netherlands

Modern traffic calming is typically said to have started with the Woonerf developments in the City of Delft, the Netherlands, in the early 1970's. A Woonerf is traditionally translated as a "living street." Woonerven are residential streets where speeds are drastically reduced through reconstruction. One might consider the first step towards Woonerven to have been in 1970 when the first road hump was built in Delft (Schlabbach 1997). The Woonerf initiative introduced the concept of shared space between vehicles and pedestrians. Formalized rules were developed in 1976. Street pavements were torn up and streets were completely reconstructed so as to favor the residential function and to reduce the domination of motor vehicles. Speed humps, chicanes, neckdowns, planters and other devices were used to both physically and visually reinforce the message that motorists are only guests in the area. Sidewalks were not allowed, since that would give the motorist an impression that pedestrians did not belong in the street. Similarly, playgrounds were to not be visible from the street; else drivers may think that children ought to play only there. (Observations from visit to Delft in 1976)

The reconstruction of streets to Woonerven became very expensive, and this technique has therefore been more or less abandoned in favor of less expensive measures while still retaining the essential traffic-calming concept. Originally, Woonerven were planned one street at a time, with heavy involvement of the residents of that street. For example, the number of parking spaces to be provided was determined at public meetings with residents. In the Netherlands today, traffic calming is frequently applied to whole areas of towns and not just to individual streets. Main traffic arteries, villages, shopping streets and town centers have all been included. Area-wide traffic-calming schemes seek to calm both the main roads and the residential roads in an area so as to improve the situation for everybody.

From the outset, the emphasis of the Dutch Woonerven was to improve the social situation as much as the traffic safety of the road. Landscaping was used to make the whole environment more pleasant to the eye. The emphasis was on style rather than function. The early evaluations focused on social interactions among children—such as playgroup size—rather than crash numbers. (Kray 1976) Traffic calming can still be said to have two major objectives; to improve the living quality of an area, and to improve the traffic safety of the area. This study focuses on the latter aspect. But it is clear that residents do appreciate the improved quality of life too. For example, a survey of some 2000 residents in Woonerven in the Netherlands found that 84% of respondents said their street was more pleasant to live in than before. (Harvey 2001)

4.2 Other European Countries

In Germany, Verkehrsberuhigung—in English, traffic calming—was introduced in the late 1970's. The concept was partially modeled after the Dutch experiments with Woonerven but less formalized. For example, street closures and diagonal diverters at intersections—similar to the Berkley management plans of the 1970's—were used as well as chicanes, humps and neckdowns (Pfund *et al.* 1980). The specific goal of traffic calming may at some locations be to reduce speeds to 50 km/h (31 mph), which is much less ambitious than the original Dutch ideas. (http://www. vickers.de/tempo50/ accessed on August 6, 2001). But, there are other towns in Germany as well as in Austria that work with Tempo 30 projects, trying to achieve 30 km/h (19 mph), or even lower speeds. Some towns have taken out curbs so that travel lanes and sidewalks are integrated in a truly traffic-calmed environment (as stated in Interessengemeinschaft für Sanfte Mobilität in Austria, Unser Verkehrsprojekt; http:// www ki-jumfo.de/projekte/verkehr.html). These streets become similar to Woonerven, sometimes referred to as "play streets" (Spielstrassen) or Traffic Restraint Precincts, with regulated maximum speeds of "walking speed." Walking speed has been fixed at 4 to 7 km/h (2 to 4 mph) by a high court decision (Schlabbach 1997)

In Denmark, there were two concepts introduced in the late 1970's: "Oppehold och legegade" which are similar to Woonerven and have a speed limit of 15 km/h (9 mph) and "Stillevej" with a speed limit of 30 km/h (19 mph). It is reported that the 30-km/h streets saw a reduction in injuries of 45% compared to before periods (Engel 1990). Arterial traffic calming in Denmark is discussed below on page 21.

Similar residential street concepts were introduced in several other countries, such as 'Hanerf' and 'Gårdsgata' in Sweden and Finland and 15 km/h streets in Austria (legislation passed in July 1983) and Switzerland (in May 1984). (Schlabbach 1997)

4.3 The United States

In most of the United States, modern traffic-calming implementations started much more recently than in Europe. For example, a traffic-calming bill for New York was signed into law on September 28, 1999. The new law permits New York City to use traffic calming techniques to design streets for speeds as low as 15 mph. The law got its start four years earlier when advocates for the concept asked the traffic-calming planners at the DOT what obstacles they faced. At the top of their list was the state law forbidding maximum speed limits below 30 mph. City traffic engineers interpreted it to mean that streets must be designed for motor vehicles to drive 30 mph or faster. As a result, most traffic calming methods were deemed unacceptable. (Transportation Alternatives 1999)

Traffic calming was implemented in several American cities prior to the New York legislative initiative. A 1997 overview covered seven cities in Florida and eleven other cities in ten different states. A conclusion of that inventory was that speed control is much more widely used than volume control—and rightly so, that is what a majority of people wants and that is what primarily improves safety. Another conclusion was that very few evaluations of crash data had been done at that time. Area-wide implementation is recommended. Notwithstanding, it seems like area-wide is defined as "covering whole neighborhoods." The arterials surrounding these neighborhoods—and sometimes going through them—are not specifically addressed in that study (Ewing.and Kooshian 1997).

The Institute of Transportation Engineers (ITE) decided at its 66th Annual Meeting in September 1996 to define traffic calming. In March 1997, a subcommittee charged with this definition came up with the following, "Traffic calming is the combination of mainly physical measures that reduce the negative effects of motor vehicle use, alter driver behavior and improve conditions for non-motorized street users." (Lockwood 1997) They also specified that traffic-calming goals include increasing the quality of life, creating safe and attractive streets, helping to reduce the negative effects of motor vehicles on the environment and promoting pedestrian, cycle and transit use. The first listed objective is that of reducing the speeds of motor vehicles.

5 ARTERIAL TRAFFIC CALMING

Traffic calming of arterials has been avoided in many jurisdictions but is starting to catch on—especially in Europe. Traffic calming techniques used on arterials in Europe as well as in North America include distinctive gateways as well as roundabouts at entry points and the construction of chicanes, road narrowings, refuge islands, planting of trees, and in some cases installation of road humps, cushions, or speed tables. Speed tables have the advantage that they provide pedestrian crossing points. Cushions have the advantage that buses and trucks can straddle them, at least partially.

In the United States most state highway department guidelines allow for vertical or horizontal traffic-calming measures only on roads classified as local roads or urban collectors, even though conditions may warrant such measures on arterials and collectors in towns not populous enough to be classified as urban. Analysis of highway crash data from Maine supports this position: About half of all fatalities and over 30% of reported pedestrian crashes occur on roads with a rural designation, but only 10% (165 out of 1589 crashes in 1994-98) of pedestrian crashes occur on sections with speed limits posted above 35 mph (56 km/h). In other words, most rural pedestrian crashes do not occur in truly rural areas but in at least somewhat built up areas with low speed limits. It may be that drivers are not respecting these speed limits, with sometimes-tragic consequences.

The Surface Transportation Policy Project (STPP) reports, "55 percent of all U.S. pedestrian deaths occur on neighborhood streets, or roads classified as local, collector or minor arterial roads." (Surface Transportation Policy Project 2002) Some crashes obviously occur in parking lots and in other 'private' areas open to public traffic, but the numbers clearly indicate that there is a substantial pedestrian safety problem along major arterials as well.

As shown in Appendix A, traffic calming that has been done on State highways in the United States is more or less limited to construction of roundabouts and narrowing 4-lane roads to 3-lanes with a center two-way, left-turn lane. Also, the primary aim of these measures is typically to reduce delay and congestion rather than to slow down traffic. Using edge lines for narrowing travel lanes from 12 feet to 10 or 11 feet may also be considered a traffic-calming measure. This has been done in, for example, New Hampshire. In other states, e.g., New Mexico, narrow travel lanes have been kept in the design when reconstructing highways.

5.1 Conventional Traffic-Calming Devices

If we exclude arterials, the most commonly used traffic-calming device in New England is the speed hump. Other frequently used traffic-calming devices include:

- Speed tables;
- Median dividers (center islands which narrow travel lane widths);
- Traffic circles and roundabouts; and
- Chicanes and chokers.

These devices are described briefly in the following sections. Then follows a discussion on non-traditional traffic-calming techniques, such as information and in-vehicle devices.

Speed Humps and Speed Tables

Speed humps and speed tables are both raised areas on the surface of roadways that are usually 3.7 to 4.3 meters (12 to 14 feet) long (measured along the travel direction of the street) and 7.6 to 10.2 centimeters (3-4 inches) high. (There are also much shorter humps, typically referred to as bumps, used at grocery stores and other locations where very low speeds are desired.) Usually they are installed in a series about 100-200 meters (300-600 feet) apart. The main differences between humps and speed tables are:

- The speed hump has a rounded top while the speed table is flat-topped.
- The speed hump is slightly shorter than the speed table.
- Tables frequently have two 1.8-meter (6-foot) ramps on each side. (Typical length of a speed table is 6.7 meters (22 feet) with a 3.0-meter (10-feet) flat section.)

Advantages of these devices are:

1. Although many people gripe about the discomfort when driving over humps, they are very effective to slow down traffic. Most drivers feel that they must drive much slower than the speed limit to achieve reasonable comfort.
2. Another evident advantage of this type of traffic-calming device is its low installation cost. The typical cost of constructing a speed hump is about $2000 (1997 dollars), making it among the cheapest of all traffic-calming devices.

Disadvantages include:

1. The speed hump and speed table have negative impacts on emergency vehicles.
2. Potential noise pollution caused by braking and acceleration, especially when the proportion of buses and trucks is high.
3. Potential damage to passing cars, especially for drivers who are not familiar with the presence of the devices.

Median Dividers (Center Islands)

The median divider is a raised island in the center of the street. The width of the divider varies according to the width and function of the street as well as pedestrian needs and maintenance and cost considerations. Usually there will be some plantings and flowers in the median but they can also be paved and act as a continuous pedestrian refuge island. Because medians slow down traffic by reducing the usable width of a street, sometime it is called "center island narrowing." Advantages of this device include:

1. The median divider is widely accepted by people because it can have an attractive appearance and improve the overall look of the neighborhood.
2. It can provide refuge for pedestrians and bicycles crossing the street. Also it helps to break up the pedestrian crossing distance, and reduce the number of simultaneous conflicts between pedestrians and vehicles.

Disadvantages of median dividers include:

1. Because usually it has plantings on it, sight distances can be worsened.
2. If it is not properly used on roads that are already narrow, it may cause difficulty for cyclists to share roads with motor vehicles. Thus coordination must be made to balance the need to slow down traffic and the requirement of cyclists to share the road.

Traffic Circles and Roundabouts

The simplest traffic circle is just a small, raised island located in the center of an intersection. Small traffic circles used in neighborhoods usually have a 4 to 7-meter (13 to 24-ft) diameter center island as illustrated in Figure 2.

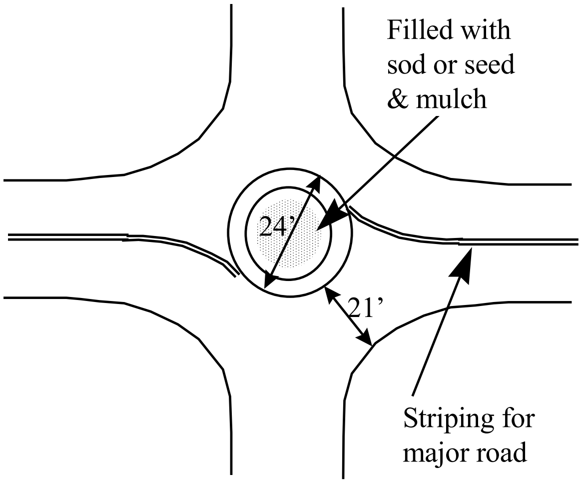


Figure 2 Typical neighborhood traffic circle, Howard County, Maryland

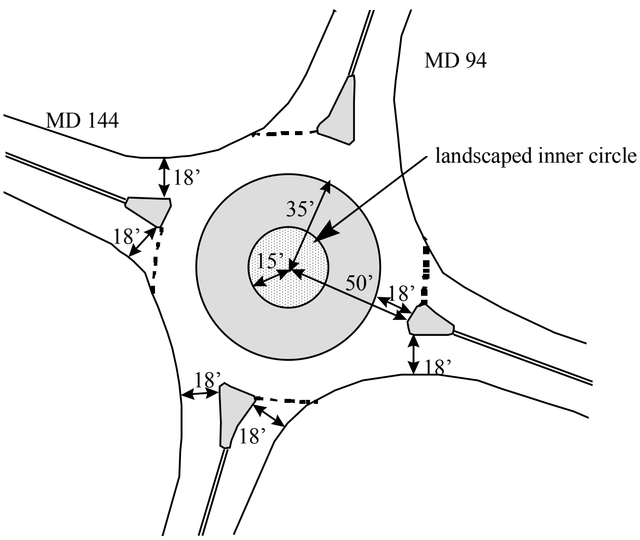


Figure 3 The Lisbon roundabout (redrawn by Gårder, based on official plan)

Because vehicles (in most states) are required to go around the traffic circle, drivers have to slow down to make themselves comfortable while going through, no matter if they go straight through or are making a turning maneuver. If the circle diameter allows high speeds, it is important that the entry is designed in such a way that drivers enter slowly. That is one of the most important characteristics of how modern roundabouts differ from older rotaries used in the Northeastern U.S. Typical modern roundabouts are shown in Figure 3 and Figure 4. An older traffic circle is shown in Figure 5.

Figure 4 The Gorham, Maine, roundabout constructed in 1997

Figure 5 The Windham, Maine, traffic circle, about 8 km (5 mi) north of the Gorham roundabout

Advantages of a well-designed circular intersection are:

1. It slows down traffic and reduces crashes according to statistical data by 50-90% compared to normal two-way stop control or signalization. (Persaud et al 2001b)
2. It can reduce mid-block speed by at least 10%.

3. It can be helpful in improving aesthetics by placing a monument or plantings in its center.
4. It reduces emissions of air pollutants by reducing accelerations from a complete stop.

Disadvantages include:

1. It sometimes takes up more land than alternative junction types.
2. A multi-lane roundabout may increase potential danger for bicycle/auto crashes.
3. It can cause delay for emergency vehicles.

Chicanes and Chokers

The chicane and choker are two similar types of traffic-calming devices that both involve curb extensions and road narrowing. The difference is that the chicane is a series of narrowings that alternate from one side to the other, thus creating a winding pattern (S-shape). Chokers include the mid-block choker and the intersection choker. By extending sidewalks or widening the planting strip, chokers give the street less usable width. Advantages of chicanes, and to some extent chokers, include:

1. Chicanes slow down traffic effectively. Chokers—like one-lane bridges with good sight distances—only slow down traffic when there is oncoming traffic present.
2. They can be good for the environment while being used as traffic-calming devices because usually plantings and flowers will be used on the extended curb.

Disadvantages are:

1. Risk of high-speed, head-on collisions at chokers lacking median dividers. Low-speed head-on collisions can also occur in chicanes lacking medians.
2. The cost is high. Average cost for constructing a chicane or choker is around $7,000-10,000. (Federal Highway Administration 2001)
3. At night, drivers may not see them in time to avoid a curb collision, especially drivers who are not familiar with the area.
4. They are not good for bicycles if they make the streets too narrow, unless a bypass opening is provided for bicyclists.
5. Motorcyclists sometimes use chicanes as a challenging obstacle course.

5.2 Alternative Traffic-Calming Techniques

Signalization

Signalized intersections as well as signalized midblock crosswalks are frequently kept and even added when arterials are traffic calmed. Actually, signalization can be used as a traffic-calming device by itself even if signalization typically increases top speeds while reducing mean speeds. One reason signals still can be used as traffic calming devices is that they reduce capacity. During rush hour this may be enough to ‘calm’ traffic. More sophisticated techniques used to control traffic with the help of traffic signals include holding back traffic on an arterial to avoid saturating downstream junctions. Applying this technique to a main arterial as part of an area-wide traffic-calming scheme could reduce queuing within the calmed length of road as long as drivers do not migrate to parallel residential streets. Physical speed reducing measures may be required to prevent traffic from speeding up once the restraining effect of the congestion is removed. When signalized junctions are relatively close together they may also be linked to provide a “green wave” for main traffic movements. This linking may be used to achieve a ‘calm’ driving speed of, e.g., 25 mph (40 km/h). In theory, drivers exceeding this speed would hit a red light and would have to wait for the other traffic to catch up. The idea is that regular road users soon would realize the benefits of driving at the appropriate speed. In practice, it is difficult to achieve such low-speed waves for a majority of drivers.

Rumble Strips

Rumble strips do not reduce speed in the same way as the above-mentioned devices. The discomfort does not increase with increased speed when traversing rumble strips. Rather, they act as an 'alarm' telling drivers to be attentive.

The use of rumble strips causes increased road noise to such an extent that such devices are not suitable in built up areas. However, a reduction in speed by itself reduces noise. Where speeds have been reduced from 50 to 30 km/h (31 to 19 mph) typical reductions in noise levels have been measured to be between 4 and 5 dB(A), but excessive use of low gears and frequent acceleration and deceleration may in some cases increase noise levels. That is also true for emissions. Typically, traffic calming gives a reduction in Carbon Dioxide and Nitrogen Oxide emissions whereas volatile organic compound emissions may go up.

Enforcement

It may be possible to improve pedestrian safety and resident quality of life along arterials without reducing speeds; however this report focuses on this approach. Similarly, speeds may be reduced through enforcement as an alternative to physical changes to the roadway. Since drivers traveling faster than average are overinvolved in crashes, the emphasis of any scheme should be on reducing the top speeds—say 85 percentiles—rather than the mean speeds. This can be done through enforcement where the risk of being caught and the consequences of being caught both play a role in deterring high speeds.[1] Automatic speed enforcement using video techniques may be a good alternative to traditional speed traps. As discussed on page 7, there is today in most of New England a low probability of being stopped when speeding. Camera enforcement may increase that probability significantly. However, there are alternatives to camera enforcement since such enforcement still targets speeders only at a limited number of sites. One such alternative is charging people for speeding, and allowing it. If the average safety cost today is eight cents per mile driven, and we assume people double their risk for every 20% they exceed the speed limit, we could, for example, charge people one cent per mile per percent (of speed) driven above the speed limit, and use GPS-based systems to keep track of driver speeds as well as of speed limits. This would mean that if someone drives at 75 mph (121 km/h) for 100 miles (161 km) where the speed limit is 65 mph (105 km/h), the limit is exceeded by 15% and they would have to pay a "speeding charge" of $15. This system would more or less legalize speeding—as long as it is not criminal speeding—but charge people for it every time they do it. With today's system, many of us drive at such 'illegal' speeds for thousands of miles a year, and have done so for decades without ever being fined. Today's situation is not good reinforcement of what legal speeds are supposed to mean. How-

[1] It should be noted that the public often argues that enforcement is the most effective way to curtail high speeds, but *Safety of Pedestrians and Cyclists in Urban Areas* by the European Transport Safety Council, Brussels, 1999, p. 12, says: "Professionals became aware that publicity and police enforcement were not the key to induce more adequate speed behaviour, and that physical design of the road could play a much more efficient role."

ever, a system that 'legalizes' speeding as long as the driver pays for it would have serious drawbacks. For example, the rich could afford to speed. That could be solved by having the 'fine' vary with a person's income, as currently is the case in the Scandinavian countries—where a Finnish executive in January 2002 was fined about $103,000 for a fairly modest speed infringement. (CNN 2001)

In-Vehicle Speed Governors

Rather than 'legalize' speeding, we could go the other way, and make it more or less impossible to speed. In several European countries, extensive testing has been done of 'intelligent' cruise controls and speed limiters, which make it impossible, or difficult, to exceed the posted speed limit. If all vehicles had such devices, sometimes speed limits could be adjusted upwards, and the limit could vary with weather and traffic conditions. One concern with such a system is that if it is impossible to go faster than the speed limit, a driver may find himself not being able to accelerate out of a dangerous situation. In reality this is seldom a real safety hazard, but it certainly can be a perceived risk. However, the system can be made such that it can be overridden, for example by just pressing the accelerator hard towards the floor. Another concern is that people may drive as fast as the system allows at all times, like bumper cars are driven at amusement parks. The European experience is that this is not happening. Rather, people will slow down to even lower speeds when they enter difficult situations less quickly. For example, a right turn that is typically made at 14 mph (23 km/h) if the approach speed is 30 mph (48 km/h) may be taken at about 12 mph (19 km/h) if the approach speed is 20 mph (32 km/h).

A first step towards a speed-limiter is already standard equipment in many cars currently sold in the United States. They have speed-warning alarms that can be set at any speed, and when that speed is exceeded, the alarm chimes until a cancel button is pushed. The alarm obviously does not rule out speeding but it makes speeding irritating. Also, Daimler-Chrysler today sells cars in the United States that have intelligent cruise controls that adapt a vehicle's speed to that of the vehicle in front.

Education

Information and education about speeding are other potential ways of reducing speeds and thereby improving pedestrian safety. The effectiveness of campaigns such as "Speed Kills" is not well documented. And like Evans (1991), Senior Researcher with General Motors, says, accidents do not occur as a result of people not knowing what to do, but by them driving in ways they know they shouldn't. Evans does acknowledge that long-term attitude changes can have an effect on behavior, but it is our belief that it would be more beneficial to make the street environment more pedestrian friendly not only in large urbanized areas, but also in rural town centers. (Van Houten et al 1997) Our hypothesis is that traffic calming is an effective means of improving the safety of all road user categories. That hypothesis will be studied in the next two chapters.

6 OVERSEES EXPERIENCE WITH TRAFFIC-CALMED ARTERIALS

Traffic calmed arterials were, as far as we know, first introduced in Norway where Strategy C in the 1970's became an alternative to Strategy A—to improve an existing road by widening and straightening it— and Strategy B—to build a bypass—as well as Strategy 0—to do nothing. Unfortunately, we have not found any safety evaluation of any Norwegian Strategy C project. However, Elvik (2001), who is from Norway, presents a meta-analysis of 33 studies that have evaluated the effects on road safety of area-wide urban traffic calming schemes from all over the world including Norway. The schemes are typically implemented in residential areas in towns in order to reduce the environmental and safety problems caused by road traffic. A hierarchical road system is established and through traffic is removed from residential streets by means of, for example, street closures, one-way systems and speed reducing devices. Main roads are improved in order to carry a larger traffic volume without additional delays or more accidents. Elvik's analysis shows that the area-wide traffic calming schemes reduced the number of injury accidents by, on average, 15%. The largest reduction in the number of accidents was found for residential streets (about 25%); a somewhat smaller reduction was found for main roads (about 10%). But, in many of these projects, the main roads were most likely not traffic-calmed.

In Denmark, traffic calming of arterial highways through towns, particularly in Jutland, was implemented in the 1980's. This includes the main highway through Vinderup. Rumble strips originally installed were removed due to complaints from residents about the noise. Resident drivers and those aged under 50 with small cars were generally in favor of the remaining measures, with non-resident drivers and those aged over 50 with large vehicles against. Remaining measures include road narrowings, islands, increased pedestrian crossings, sidewalk build-outs, bike paths, and planting/landscaping. (Herrstedt 1988)

An evaluation of traffic calming of arterials through this and two other Danish towns were published in 1993. (Vejdatalaboratoriet 1983) The compact areas of the towns have around 3,000, 4,000 and 1,000 inhabitants respectively. The traffic volume (AADT) on each of the through roads is between 4,000 and 5,000. The intended "traffic-calmed" speeds vary between 40 and 50 km/h (25 to 31 mph). The traffic-calmed sections vary in length from 0.8 km to 1.2 km (0.5 to 0.75 miles). Pedestrian volumes crossing the arterials vary between 500 and 1,050 for a 7.5-hour daytime period. The number of crossing bicyclists is almost identical to the number of crossing pedestrians. The published safety evaluation is a comparison of crash numbers for a five-year after period compared to what would have been expected had the reconstruction not occurred. That latter number was calculated as the before number (for a 5-year period) corrected linearly for changes in vehicle volumes and the general change in crash rates and vehicle volumes for 22 towns in the 3-4,000 population range and 20 towns in the 1,000 population size. The results are summarized in Table 2.

The authors of the study conclude that the reconstructions in Vinderup and Skærbæck (especially if excluding the signalized location) were very effective with reductions in crashes of 40% and 33% respectively. However, it is our belief that regression-to-the-mean effects may account for at least some of the reported effectiveness, since it seems strange that the before crash rates would be that much higher for these locations than for the control towns. However, we do not know if there are specific reasons explaining why the experimental towns would have higher crash rates than the surrounding towns. It should also be noted that serious injuries were reduced more than all crashes. Even in Ugerløse, where the total number of crashes increased after reconstruction, the injury crashes went from three to one. For the three towns together, the injury crash number went from 31 to 14 (reduction, $p<0.01$) if including the signalized location and from 25 to 8 (reduction, $p=0.002$) if the signal is excluded. The number of pedestrian crashes went from eight in the before period to two in the after period (reduction, $p=0.055$).

Also in Denmark, a main road carrying 20,000 vehicles per day was traffic-calmed through Hellerup, a suburb of Copenhagen only a few miles from the city. This road has been calmed over a length of several kilometers. Neckdowns, frequent pedestrian crossings, offsets and bike paths were included while road humps were not used. Speeds have been reduced, although safety problems are reported to still remain (Hopkinson et al 1989).

Outside Scandinavia, traffic-calmed major roads in Europe include an experimental traffic-calming scheme implemented on Shenley Road through the town center of Borehamwood, England. The road carries some 18,000 vehicles per day. Conditions for pedestrians have been improved and vehicle speeds reduced. Measures include road narrowing, islands, flat-top humps used as pedestrian crossing points, and the replacement of traffic lights by mini roundabouts. No safety evaluation is presented on this website (Harvey 2001). That is the case for the following seven projects as well. The information is taken from the same Internet source.

Kalker Strasse is a main radial road in Köln, Germany with intensive shopping, commercial and apartment uses. Following the opening of a new radial road the traffic function of Kalker Strasse has been downgraded. A one-way section has eliminated westbound through traffic such that AADT has been reduced from 27,000 to 13,000. There has been some speed reduction, especially during shopping hours, however accident trends are reported as 'disappointing.' Measures include road narrowing (18 m to 7 m; or 60 to 23 feet)), one-way sections, parking provision, loading lane, tree planting, light controlled pedestrian crossings.

Table 2 Number of crashes per million vehicle kilometers

Location	Population	Before	Recorded after	Expected after
Vinderup	3,000	3.0	1.5	2.5
Skærbæck incl. signal	4,000	2.4	1.4	1.8
Skærbæck excl. signal	4,000	1.6	0.8	1.2
Ugerløse	1,000	1.0	1.6	0.9
Control	3-4,000	1.2	1.0	--
Control	1,000	1.1	0.9	--

Traffic calming on adjacent roads had forced traffic onto Leenderweg, a main radial street into Eindhoven, the Netherlands. Suburban shopping and commercial activities occur along much of its length, together with housing. Traffic calming has succeeded in moderating vehicle speeds, and made crossing easier for pedestrians at an overall cost of about $500,000 for a 0.5 km (0.3 mi.) length of road. Measures here include road narrowing, a parallel service/parking road, bike paths, light controlled pedestrian crossings, islands, and tree plantings.

Main road calming in Ingolstadt, Germany, is reported to have been ineffective, in part due to the use of rumble strips which were later removed due to complaints about the noise. Other measures included central islands, pedestrian crossings originally protected by rumble strips, tree plantings, and bus stops organized so that buses using them block the travel lane.

Langenfeld, Germany, is a town of about 50,000 inhabitants. Its main street carries about 10,000 motor vehicles per day together with buses and some 3,000 bicycles. Speeds have been reduced to less than 40 km/h in the vicinity of speed cushions and conditions for pedestrians have been improved, although the specially designed crossing places are not always used. Parking in defined on-street spaces also helps to keep speeds down by interrupting the flow of traffic. Traffic calming measures used to reinforce the 40-km/h speed limit are road narrowings, cushions, raised junctions, islands and bicycle lanes.

Route de Nantes through Rennes, France was prior to traffic calming a 4-lane road carrying 15,000 vehicles per day. In 1987, the road was narrowed and given islands, chicanes, a mini-roundabout, bicycle paths, and tree plantings.

St John's Hill, Wandsworth, England is a busy inner London Street with a mixture of shopping and commercial usage. Two-way traffic flow on this road exceeds 2,000 vehicles per hour in the morning peak. Measures include road narrowing, islands at pedestrian crossings, parking bays, ramped side road entrances, tree plantings.

In 1987-88 plans were developed to use a combination of traffic signals and other measures to traffic-calm Sowerby Bridge, England. The proposals involved forming traffic platoons outside the main shopping area using traffic signals, and by careful timing allow the traffic through the town so as to leave significant gaps for pedestrian crossing movements. The design of the platoon control was based on a running speed between control points of 30 km/h (19 mph). For a variety of reasons, however, these proposals have not been carried out. (Harvey 2001)

Traffic calming of arterials is considered in Australia, too, as indicated by the statement, “The scale of traffic calming clearly need not be limited to ‘local areas.’ Road authorities need to think seriously about their attitude to traffic impacts on arterials and sub-arterials; traffic planners and engineers have the tools if authorities have the will.” (Harvey 2001)

From the above sources, not much can be concluded about the effectiveness of traffic calming of major streets. However, it is ‘known’ (or at least believed) that the impact of traffic calming schemes on accident levels depends on the speed reducing effect of the scheme and on any reduction in traffic levels as a consequence of it. There is a general consensus that lower vehicle speeds not only reduce the occurrence of accidents, but also have a significant effect on their severity. However, there is not much evidence in the analysis presented above that national safety levels so far have been drastically impacted in any country by traffic-calming schemes focused on arterials. On the other hand, over just ten years, pedestrian fatalities in West Germany fell from

6.2 to 2.3 per 100,000 population. This has been largely attributed to lower vehicle speeds in urban areas, primarily as a consequence of heavy investment in traffic calming. (Mathew 1992) An overall reduction in personal injury accidents of 41% has been achieved with the Berlin Moabit scheme, with a reduction in fatalities of 57%, and serious injuries of 45% (Pharoah and Russell 1989), and the overall effectiveness of traffic calming is undisputed if we widen the horizon past arterials. A review of 600 traffic-calming schemes in Denmark has indicated that there has been a reduction of 43% in casualties compared to untreated areas (according to Web site http://www.its.leeds.ac.uk/projects/primavera/p_calming.html#a1 discusses accessed September 20, 2001). And, the U.S. experience is very similar. The safety effect of some select measures is shown in Table 3. Obviously, regression-to-the-mean effects may explain some of the presented effectiveness.

Table 3 Safety impacts of traffic-calming measures (U.S. experience)

	Average Number of Collisions		
	Before treatment	After treatment	Percent change in collisions
12-foot humps (49 observations)	2.7	2.4	-11%
14-foot humps (5 observations)	4.4	2.6	-41%
22-foot tables (8 observations)	6.7	3.7	-45%
circles (w/o Seattle) (17 observations)	5.9	4.2	-29%
circles (with Seattle) (130 observations)	2.2	0.6	-73%

Source: Reardon (2001)

7 TRAFFIC CALMING OF NORTH AMERICAN ARTERIALS

7.1 The United States

The ITE Traffic Calming website (Traffic Calming 2001) states in Chapter 9—Beyond Residential Traffic Calming—that, "Most communities have arterials or collectors with fronting residences. They may be rural highways passing through small towns or neighborhood streets at the end of tributary networks. Whether by design or as a result of growth, thousands of vehicles per day race past homes, schools, and parks, spurring residents to call for traffic calming to restore the quality of life. In many communities, their request is rejected with the rationale that traffic calming is not appropriate on higher order streets." The web site goes on to say that some people believe that traffic calming can offer an improvement in safety and quality of life on such streets, even though others disagree. They quote a British report stating, "Making 99 percent of a journey safe and convenient by foot or bike is futile if the remaining one percent contains a dangerous road crossing." We agree with that, and want to add, that if, before any traffic calming is initiated, more than 90% of the pedestrian crashes in a town occur along the major highway going through the town—like in Oxford Hills, Maine—then traffic calming of residential streets makes little sense in that community. It is obviously the State highway that needs the improvement in the form of traffic calming or some alternative treatment.

Page 175 of the ITE report (Traffic Calming 2001) gives some examples of U.S. experiences with traffic calming of major streets. It describes how Hollywood Boulevard, a major arterial through Hollywood, Florida, was reduced from a five-lane road to one having only two lanes through the downtown area. Wide sidewalks were added and the economic decline of the downtown was reversed. However, no safety evaluation is presented. Another example described in this report is a major collector in Columbia, Maryland, which was equipped with warning signs, speed humps, chokers, circles, and speed tables. Again, no safety evaluation is provided. Also, in Portland, Oregon, an "Arterial Traffic Calming Program" was initiated in 1993. The name was soon changed since the program only targeted streets designated as neighborhood collectors having at least 75% residential frontage. Central to the program is that no collector project diverts more than 150 vehicles a day to a parallel local street. Neckdowns, center islands, split medians, and 22-foot speed tables are used on these collectors. Traffic circles and 14-foot humps are not allowed. Staff evaluations rather than neighborhood request are the basis of whether measures are to be implemented or not. Eleven collectors with volumes up to 7,600 vehicles per day were calmed under this program by 1997. A moratorium was then put in place until 1999 since concerns about these measures on emergency response routes were raised.

Roundabouts are the major feature of a traffic-calming demonstration project of a section of New York State Route 114, a state arterial. The design also includes gateway treatment, intersection realignment, curb extensions, raised medians, narrowed lanes, textured crosswalks, rumble strips, bike lanes, pedestrian lighting and streetscaping. A survey of residents revealed that 95% of respondents favored the work on the completed half of the project. (Reardon 2001) It is still too early to evaluate safety from crash data.

Searching the links provided in the FHWA website (http://www.fhwa.dot.gov/

environment/tcalm/index.htm, accessed on August 9, 2001) on traffic calming shows that some communities besides Portland, Oregon, for example, Albuquerque, New Mexico, have traffic calming projects with tailored speed control of selected collector roads but very few cities, if any, have projects on arterials. Safety evaluations are not presented.

Roundabouts

A recent analysis by Persaud and Gårder of 'all' modern U.S. roundabout installations shows that fatal and incapacitating injury crashes were reduced ($p = 0.0000000005$) from 42 to 3 for similar time periods and with slightly higher total AADT for the after period. (This is a statistically significant reduction of over 80% ($p=0.05$).) Less serious crashes were also reduced. After controlling for regression-to-the-mean effects the overall best estimate of the crash reduction was calculated as 40 percent, and the reduction of injury crashes as 80%. The before control varied and included signalization at some locations, two-way stop at the majority of sites, and all-way stop at a few places. The main reason that serious injuries were reduced so effectively is most likely the reduction in speed. This reduction did not come at the cost of increases in the average travel time, but typically the opposite was achieved. (Persaud *et al.* 2001a) Roundabouts reduce typical travel speeds to about 15 mph through the intersection. Often the 'before' speeds were more than double that. In other words, roundabout installations calm traffic. However, since they also improve mobility by reducing travel times through the intersections, they sometimes may attract traffic. Roundabout construction is therefore typically not seen as a traffic-calming scheme.

Stevens Avenue, Portland, Maine

Stevens Avenue in Portland, Maine, is classified as a minor arterial. (Its location is near the center of the map in Figure 6.) It carries around 12,000 vehicles a day according to Maine DOT's official website "The 1999 Maine Transportation Count Book," http://www.state.me.us/mdot/traffic/1999book.pdf accessed September 20, 2001. There are several schools along the street, with a total of about 2,500 students attending them. The traffic-calming project was initiated in 1993 at the request of neighborhood residents and highlighted by an incident in January 1997 when a crossing guard in a crosswalk was struck by a vehicle which failed to yield.

Traffic-calming measures were installed (between Forest Avenue and Brighton Avenue) in October 1997. The initial measures, installed on a temporary basis, included striping bike lanes, installing medians, constructing chicanes and neck-downs, and raising an intersection. Some of these measures—especially the neckdowns and the chicanes—created immediate concerns and were taken out.

The permanent measures include striped 'shoulders,' three raised crosswalks, a raised intersection, two speed tables, an electronic sign advising motorists to stop for pedestrians in crosswalks, and a new traffic signal. The City Council passed a traffic-calming ordinance in March 1999.

As a result of the reconstruction, vehicles have been slowed by as much as 15 mph and pedestrians are having an easier time crossing the busy north-south artery. The traffic calming has also caused a diversion of some through traffic. Traffic volumes on Stevens Avenue were reduced by 10 to 17%. Through traffic on Stevens Avenue was reduced by approximately 40%. The traffic volume increase on parallel streets was minimal according to the May 1998 evaluation, though that report does not discuss what happened to this traffic (Stevens Avenue 1998). In spite of the reductions in traffic volumes on Stevens Avenue, the emissions of volatile organic compounds went up (Shanahan 1998). Surveys of drivers, pedestrians and residents in the spring of 1998 showed that there was roughly a 2:1 majority favoring the traffic-calming project (84 in favor, 46 not in favor, 24 did not care either way) (Stevens Avenue 1998).

The May 1998 Final Monitoring Report tells us that the crash frequency on this section before the installation was 0.65 crashes per month, while there were 5 reported crashes in the first 5 months after the installation. There is an 11% chance that this increase was caused by a random fluctuation rather than a true decrease in safety. And since the time periods are very short, expanded crash data is needed for an analysis. Therefore, crash data was requested from Maine Department of Transportation. This data is presented in Table 4.

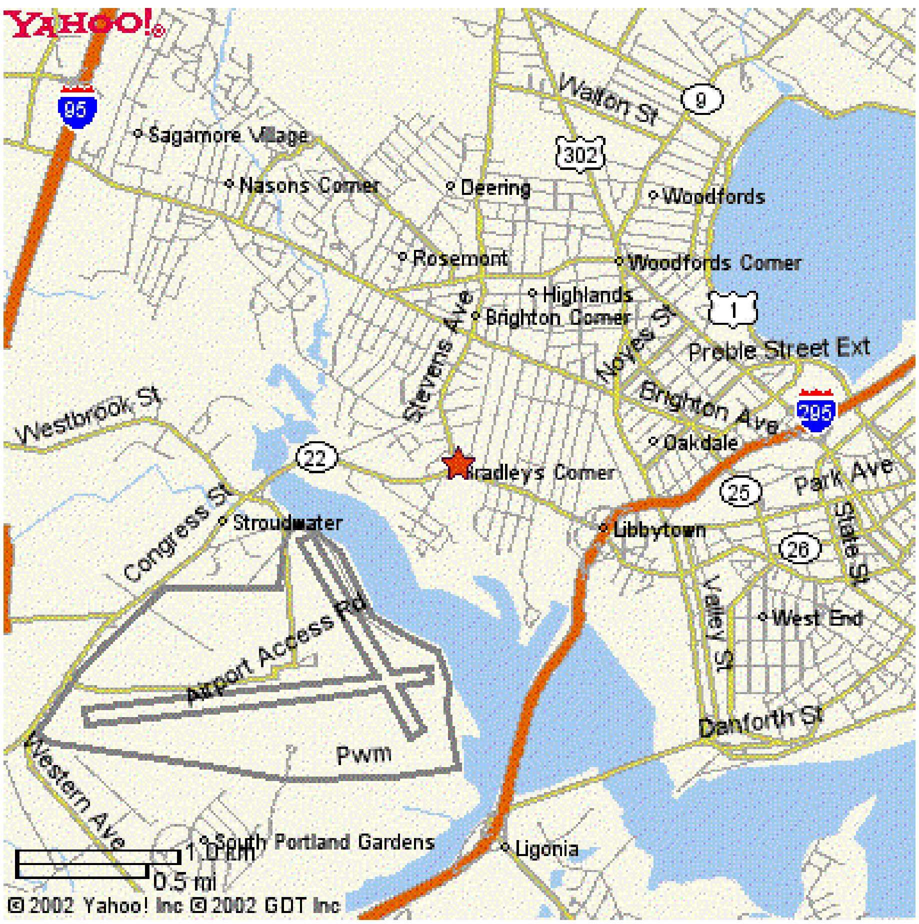


Figure 6 Stevens Avenue, Portland, Maine

Table 4 Crash numbers—Stevens Avenue from Woodford Street to Forest Avenue

		Injury crashes	Possible injury crashes	Property damage only	Sum	Pedestrian crashes (included in total)
Before	1994	7	12	36	55	--
	1995	7	8	31	46	3
	1996	4	14	31	49	1
	sum	18	34	98	150	4+
Construction	1997	--	--	--	--	--
After	1998	6	11	40	57	1
	1999	3	5	34	42	0
	2000	2	11	29	42	0
	sum	11	27	103	141	1

The table shows that the total number of crashes is more or less unchanged after reconstruction in spite of a small drop in traffic volumes. However, if 1998 is excluded, the year only temporary measures were in place and the year drivers were getting used to the scheme, there has been a clear tendency towards a reduction in overall crashes (p=0.057). A goal was to improve pedestrian safety, and the number of pedestrian crashes went from four in a two-year before period (detailed data for 1994 is not available) to one in the three-year after period. There is an 8.7% chance that this is not an improvement; in other words, the reduction is not statistically significant. The same goes for the reduction in injury crashes. There is a 13% chance that the reduction in 'injury crashes' is a random event and an 8.5% chance that the reduction in injury crashes including possible injuries is not caused by a true improvement in safety.

In conclusion, the traffic calming of Stevens Avenue seems to have marginally improved safety. However, the improvement is not a 50% reduction, the minimum a traffic-calming scheme ought to achieve in our opinion. However, it is possible that the 'after' crashes occur at locations that have not been properly traffic calmed. The experience from Denmark, see Table 2, shows that the effectiveness of traffic calming is greater if the (non-traffic-calmed) signalized locations are excluded from the analysis. Maybe that would be the case here too. We do not have access to detailed crash data for 1994. For the remaining before period, there were in 1995 22 reported crashes and in 1996 18 crashes at traffic signals operating with stop-and-go phasing. For the after years, there were 27, 23 and 26 such crashes respectively at signals. It should be noted that a new traffic signal was installed here. Still, if we exclude these crashes, the overall effectiveness of the scheme (all severity types) becomes 21% [(27.5-21.67)/27.5] rather than 6% [(50-47)/50]. And it should be kept in mind that the reduction in injury crashes—as indicated by Table 4—is larger than this. It is definitely notable that 79 (if we include three crashes at the signals occurring at flashing operations) of the 141 crashes in the after period occur at the signals. Future safety improvement schemes to this section must obviously not overlook the fact that 56% of the crashes happen at signals. Perhaps replacing them with roundabouts would be a feasible strategy.

7.2 Canada

Canadian traffic-calming deliberations have traditionally excluded arterial roadways; at least that was the case back in 1997 (Skene *et al.* 1997). The 'current' traffic calming practice is described in "Canadian Guide to Neighbourhood Traffic Calming," TAC/CITE, December 1998. This can be viewed at ITE's website (http://www.ite.org/traffic/tcstate.htm#cgntc, accessed on August 9, 2001). There is in this guide no discussion about traffic calming of arterials. However, a recent paper published by ITE on the subject shows that there are traffic-calmed arterials in British Columbia (Skene *et al.* 1999). One of the examples discussed is from Victoria, B.C. where a four-lane road (Cook Street) was narrowed to two lanes, had all-day parking installed as well as pedestrian refuge islands. Traffic volumes were not changed but 85th percentile speeds were reduced from 51.4 km/h (31.9 mph) to 46.5 km/h (28.9 mph). Crash numbers were reduced from an average of 35.75 per year to 19 per year. The other example presented in this paper is from Smithers, B.C. where gateways were being built along Highway 16 through the town at the time the paper was written. This section of the road previously appeared to be just a continuation of the wide, rural highway.

There are other, more radical, traffic-calming schemes in Canada. But they are still not evaluated. For example, the Region of Ottawa-Carleton (in Ontario, Canada) has installed a series of speed humps on Lyon Street, an arterial road at the outskirts of the CBD in an older, core residential area. The devices were installed in the fall of 1998. The road is a major commuter route between the downtown employment area and the freeway that provides access from the suburbs. There is a partial interchange with the freeway on this road. Also, there are four or five other calmed street initiatives in the city area, which fall under arterials/major collectors. The Lyon Street speed-hump project is the most controversial one according to their Public Works Department. They also say,

> "Unfortunately, the city's collision statistics program was being revamped over the past couple of years; collision data was delayed in being processed. This has resulted in collision data just recently being available. If one was to look at just the collision data, the Lyon Street vertical measures seem to have had a significant impact on collision reduction. However engineers are currently looking at the data in detail and assessing other traffic data elements such as traffic shifts to gain a full appreciation the vertical measure impacts." (August 10, 2001 e-mail from Mr. Greg Kent, Utilities and Public Works Department, City of Ottawa.)

And,

> "Aside from the Lyon Street project, none of the other traffic-calming projects undertaken have seemed to produce the same collision reduction results. As with Lyon Street, data are being analyzed to gain a full appreciation of what works and why, but results are still not available." (September 20, 2001 e-mail message from Mr. Bob Streicher, Utilities and Public Works Department, City of Ottawa.)

8 DISCOMFORT AND ACCEPTANCE

The intent with traffic calming is to slow down traffic to 'safe' speeds and at times to reduce volumes to environmentally acceptable levels. This paper deals mainly with the safety benefits of traffic calming, and volume control is then a secondary issue, since safety improvements (in percent) are roughly proportional to the square root of the volume reduction (in percent) whereas the safety improvement—weighted by injury severity cost—is roughly proportional to the speed reduction cubed. (Gårder 1997)

The intent with traffic calming is not—according to the authors of this report—to make it annoying to travel by motor vehicle. Others may not share this view, but we believe that traffic calming will never succeed in North America unless people perceive that they can travel with approximately the same level of comfort as prior to the traffic-calming implementation.

8.1 Discomfort

The best way of measuring discomfort in vehicles is probably to have the occupants of the vehicles rate the discomfort themselves, rather than measure it with sophisticated accelerometers that may or may not coincide with people's perceptions. One of the investigators has previously performed such studies and also studied the comfort of seated as well as standing bus passengers across humps. The results of these studies are summarized in the next two paragraphs. An article presented in the January 2000 ITE-Journal (Weber and Braaksma 2000) also addresses discomfort measurements.

The conclusion of the discomfort studies (Gårder and Hyden 1979) is that it is possible to construct humps such that the discomfort is low at speeds around, for example, 20 mph (30 km/h) and with increasing discomfort with increasing speed. For example, Figure 7 shows the average discomfort experienced in a passenger vehicle when traversing a 9-meter (30-ft) long, 15-cm (6-inch) high circular hump and a 3.7-meter (12-ft) long, 9-cm (3.5-inch) high hump.

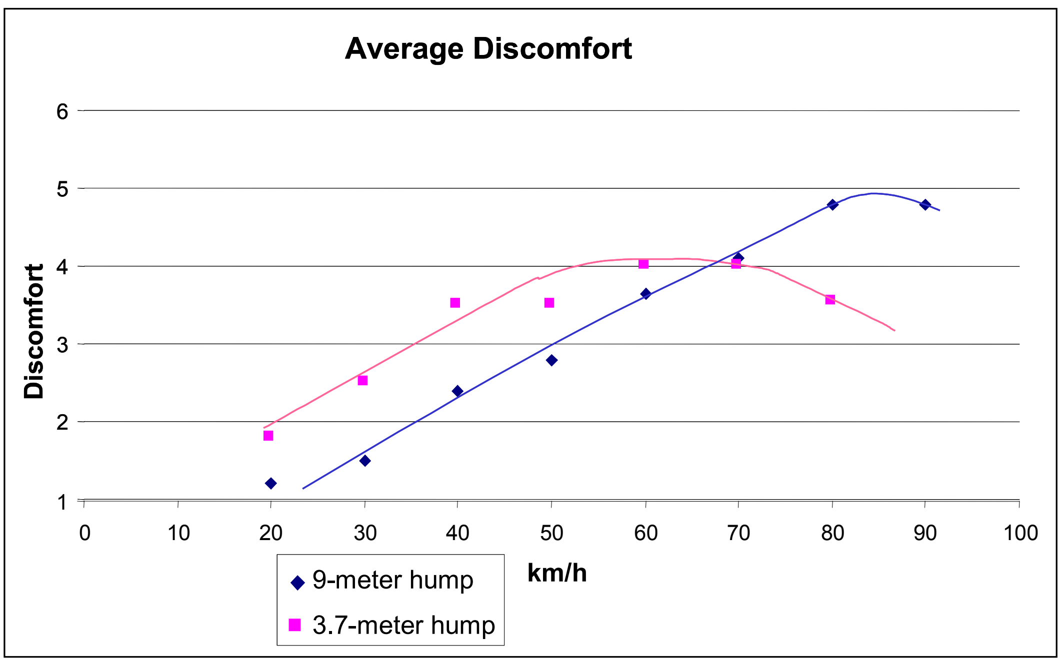


Figure 7 Discomfort when traversing humps

The highest discomfort that could be recorded was 5, and 1 indicates no discomfort. Three passenger cars and one van were used, with a total of 17 passenger observations for each speed. Tests were also done with a fire truck (Scania) and an ambulance (International Harvester). The discomfort to passengers in the fire truck were, surprisingly, lower than in the passenger cars. On a stretcher in the ambulance, the discomfort was slightly greater at all speeds than the averages presented here.

Measurement of the discomfort of 19 passengers in a bus are shown in Table 5, using the same scale as in Figure 7, where 1 is no discomfort and 5 is 'intolerable.' (Gårder 1982)

Table 5 Average discomfort of standing and seated bus passengers

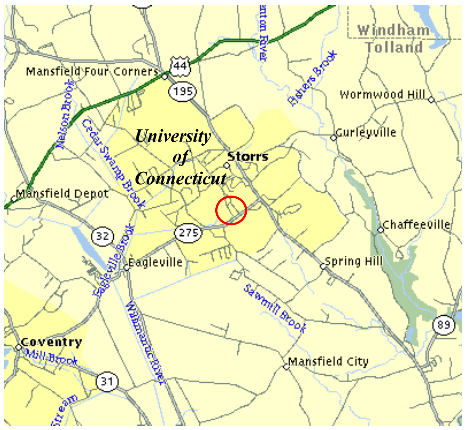
Situation	Discomfort
Emergency braking from 50 km/h	4.3
Hard braking from 25 km/h	3.9
3.7-meter hump at 30 km/h	3.6
3.7-meter hump at 40 km/h	3.3
3.7-meter hump at 50 km/h	3.2
40 km/h travel on bad pavement	3.2
3.7-meter hump at 25 km/h	3.1
90-degree right turn at 20 km/h	2.7
3.7-meter hump at 20 km/h	2.1
Normal stop at bus stop	2.0
3.7-meter hump at 10 km/h	1.6
3.7-meter hump at 5 km/h	1.4
Gentle left turn at 20 km/h	1.3
Normal travel on excellent pavement	1.0

8.2 Connecticut Study of General Population and Residents

To learn about people's perception and acceptance to different traffic-calming devices, we conducted surveys in two Connecticut towns where traffic-calming devices have been installed. Two kinds of surveys were conducted. One is a resident survey, in which we interviewed residents on the street where a traffic-calming device was located. The other is a public survey, in which we randomly interviewed members of the public who did not live on the streets with the traffic-calming devices, but were familiar with them. These individuals were interviewed in public places such as shopping centers and on streets in the town center. The survey forms we used are shown in Appendices B and C. In general, questions in our survey form were designed to acquire information in four areas:

- Basic information of survey respondent. This includes gender, age range, and whether or not he or she has children younger than 16. These questions help us to investigate how opinions about traffic calming vary by these demographic characteristics.
- Degree of acceptance of traffic-calming devices. We asked respondents to report their perception of the specific traffic-calming devices as a nuisance on a scale of 1 (no nuisance) to 5 (intolerable).
- Effect of devices. Here the question differed by respondent category. We asked residents who lived on a street with a traffic-calming device to report their perception of the effect it has of slowing down traffic, again on a scale of 1 (no effect) to 5 (extremely effective). For the public survey, we asked respondents how they might have changed their driving speed along the street with the traffic-calming devices since the device was installed.
- Impact on route choice behavior. We asked the residents whether or not their travel patterns changed due to the traffic-calming devices, again on a scale of 1 (not at all) to 5 (major changes). In the public survey, we asked each respondent to describe how frequently they drove on the street both before and after the traffic-calming devices were installed, again on a scale of 1 (never) to 5 (every day).

Altogether, we interviewed 183 people: 102 in Storrs (70 public and 32 resident) and 81 in West Hartford (50 public and 31 resident). There are three types of traffic-calming devices: 1) speed humps (located in both Storrs and West Hartford), 2) medians and 3) winding street pattern (only located in West Hartford).



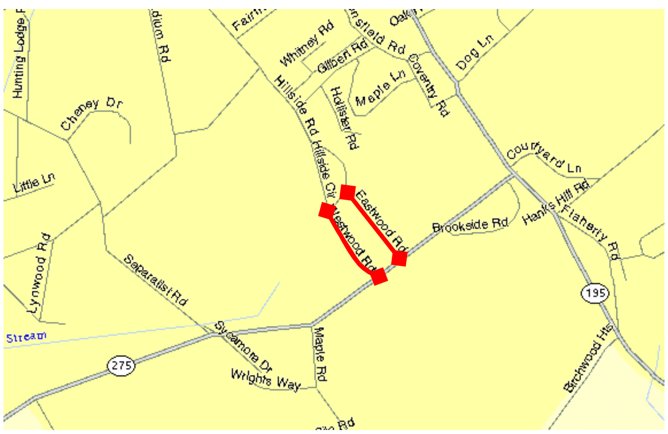


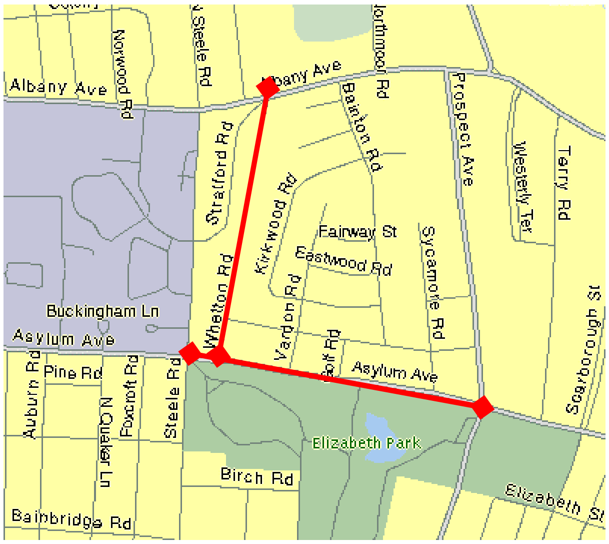
Figure 8 Westwood and Eastwood Road in Storrs

In Storrs, the traffic-calming devices are located on Westwood Road and Eastwood Road adjacent to the University of Connecticut (see Figure 8). These two streets connect directly to an entrance to the University campus, and serve as a convenient short cut for drivers wishing to avoid signals at the main entrance to the campus. Two speed humps have been installed on each road, each about 3.7 meters (12 feet) long and placed 155 meters (500 feet) apart. Figure 9 is a photo of one of these humps.

Figure 9 Speed hump, Storrs

In West Hartford, three streets were selected, at the suggestion of the Town traffic engineer:

- Whetten Road, also with speed humps, but spaced at approximately 210 meters (700 ft). (See Figure 10a and Figure 11.)
- Asylum Avenue, which has newly installed medians and plantings. This is an arterial street, originally four lanes wide, now with one lane in each direction, with left turn lanes shadowed by the median and parking on one side along a large public park. (See Figure 10a and Figure 12.)
- St. Charles Street, which was originally a two-way, two-lane street with a width of 9.1 meters (30 feet), but has now been rebuilt with a width of 6.7 meters (22 feet) in a winding pattern and designated with one way traffic. Note that there are several community shopping centers and a freeway interchange located on the street directly east of St. Charles Street. (See Figure 10b and Figure 13.)



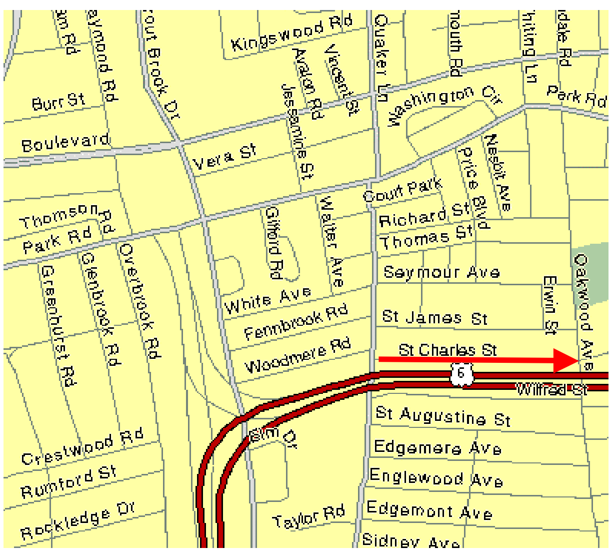


Figure 10 a) Map of Whetten Road and Asylum Avenue. (West Hartford, above, top)
b) Map of St. Charles Street. (West Hartford, above)

Figure 11 Speed Hump, West Hartford

Figure 12 Median, West Hartford

Figure 13 Winding pattern, West Hartford

We surveyed public and resident perceptions of three types of traffic-calming devices: speed humps, medians and winding street patterns. Previous research suggests that patterns in people's opinions about traffic-calming devices vary somewhat for different types of devices. Consequently, we analyzed patterns in the survey responses by type of device.

Humps

Public Surveys

Respondents to our public survey were mostly University of Connecticut commuting students and staff in the case of the Storrs survey, or town residents in the case of the West Hartford survey. Consequently, these individuals are regular users of the streets with the subject traffic-calming devices, and therefore can be expected to care about the traffic condition on these streets.

According to the data gathered, we reach two conclusions.

1. Changes in frequency of use: Of those who reduced use of the streets (altogether 12 out of the sample size of 76), 7 out of 12 claim it is the hump that caused them to reduce their travel on that street. These seven respondents all indicated that they "hate" speed humps. As to the other five, two expressed mixed feelings about the humps. In other words, they understand why the humps were installed, but still harbor negative feelings about them. They did not specify whether or not the reason for their reduced use of the street is due to the humps. The remaining 64 respondents didn't change their usage frequency at all.
2. Changes in speed: Regardless of their unpopularity, speed humps appear very useful in slowing down traffic according to the self-reports. Of all the 51 respondents who admitted that they used to drive faster than the speed limit on the streets, 34 reduced their speeds due to the speed humps. One respondent in Storrs claimed to have always driven slower than the speed limit on these streets, and now drives even slower with the humps.

Resident Surveys

Due to the limited number of residents along the streets where humps are located, the size of the survey samples is not large. Altogether we interviewed 41 individuals, of which 32 were residents of the streets in Storrs and nine of the street in West Hartford.

In Storrs, nearly 70 percent of the residents surveyed on Westwood and Eastwood Roads are retired faculty members of the University of Connecticut and have lived there for at least 30 years. In West Hartford, the residents surveyed had lived on Whetten Road an average of 4 years.

After completing an early phase of these surveys, we decided that some individual demographic characteristics are likely to be correlated to respondents' opinions about traffic-calming devices. So we added questions to our survey asking whether or not each respondent is married and has children younger than 16, as well as recording each respondent's gender. However, since these questions were added during the last phase of the survey, only records from West Hartford and some of the records from Storrs contain these variables.

As we had expected, few residents changed their travel habits because of the speed humps. Only 10 out of 41 claimed that they changed their travel habits at all. As a matter of fact, only one respondent ranked this as a 5 and one as a 4. The remaining eight ranked it as 2 or 3, which cannot be called a substantial change in travel habits. Therefore, our conclusion is that humps do not substantially affect most residents' travel habits.

The mean value of the response about

the effect on slowing down traffic of humps is 3.0, which means that the hump is seen as fairly effective. An interesting phenomenon is that in Storrs, where the average resident age is higher than in West Hartford, (the modes are 56-65 and 36-45, respectively) the average evaluation scale is 3.3. This value is a little higher than the overall average value of 3.0. Unfortunately, due to this geographic correlation and the fact that survey numbers are small, we cannot distinguish between the possibility that this difference is attributable to differences related to the towns as opposed to age of respondents.

Integrated Analysis

Table 6 summarizes differences in reported nuisance rating for all three types of devices among categories of the demographic variables. Following is specific discussion of these figures.

Fifteen records included the gender variable. Since the median and mean of females' evaluation scale of nuisance are both higher than that of males, we can say that females' impression of humps is somewhat worse than that of males.

Among the overall 117 records, 59 gave us additional comments. Twenty-one out of 59 said that they preferred the humps for traffic calming, and 29 explicitly expressed their strong objection to installing the humps. The reasons are diverse. The most common complaint was that a hump is inclined to damage cars and make people feel uncomfortable. Nine respondents expressed mixed feelings about the humps. They can understand installing humps on street, but they feel that it still needs more improvements to be accepted by drivers and residents.

Table 6 Nuisance Scaling by Age, Gender and Children Factor, Each Type of Device

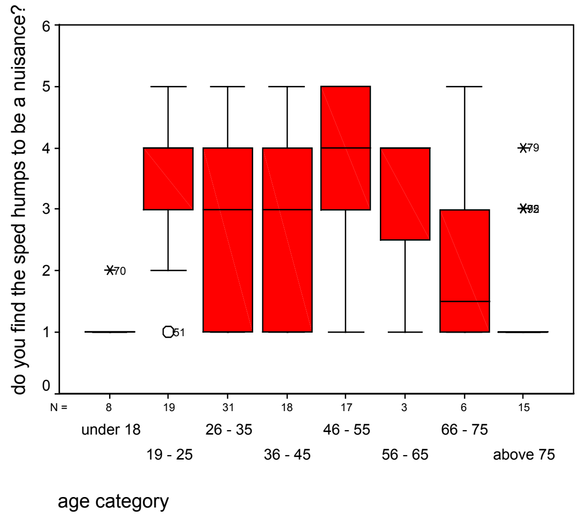
Device / Factors	Hump			Median			Winding Pattern		
	Number of cases	Mean	Median		Mean	Median	Number of cases	Mean	Median
Age Category									
18 and under	8	1.13	1.00	1	4.00	4.00	2	2.50	2.50
19-25	19	3.53	4.00	2	2.50	2.50	6	2.83	2.50
26-35	31	2.71	3.00	4	1.75	1.00	4	1.00	1.00
36-45	18	2.72	3.00	6	1.50	1.00	12	1.92	1.00
46-55	17	3.59	4.00	10	1.60	1.00	11	1.73	1.00
56-65	3	3.00	4.00	2	1.00	1.00	3	3.33	4.00
66-75	6	2.17	1.50	1	1.00	1.00	2	4.50	4.50
Above 75	15	1.47	1.00	0	N/A	N/A	0	N/A	N/A
Total	117	2.68	3.00	26	1.69	1.00	40	2.17	1.00
Gender									
Male	7	1.71	1.00	13	1.77	1.00	15	2.60	2.00
Female	8	2.25	1.50	13	1.62	1.00	25	1.92	1.00
Total	15	2.00	1.00	26	1.69	1.00	40	2.17	1.00
Children under 16									
Have	7	1.71	1.00	9	2.00	1.00	16	1.94	1.00
Have none	12	2.50	2.50	17	1.53	1.00	24	2.33	1.00
Total	19	2.21	1.00	26	1.69	1.00	40	2.17	1.00

Just as we expected, people who have children younger than 16 prefer humps compared to those who have no children younger than 16. From Table 6 we can see that the average value for people who have children younger than 16 is 1.7 while the average value for those who have no children is 2.5.

Table 7 lists the number of responses by age category for each level of nuisance scaling; a box plot of these estimates is given in Figure 14. The group median in each age category is marked out specifically. Although there is no absolute increasing or decreasing tendency, we do see some pattern. The median of nuisance scale of each category first increases, until it reaches its highest value for age range 46-55. Then the median value of the nuisance scale begins to decrease. In other words, younger respondents and older respondents are more inclined to accept traffic humps than middle-aged respondents.

Table 7 Detailed Nuisance Scaling by Age (Hump)

	1 = Not a nuisance > > > > > > 5= Intolerable				
Age\	**1**	**2**	**3**	**4**	**5**
under 18	7	1	0	0	0
19-25	1	1	5	11	1
26-35	9	5	6	8	3
36-45	7	0	4	5	2
46-55	0	1	2	5	6
56-65	1	0	0	2	0
66-75	3	1	1	0	1
above 75	12	0	2	1	0



The scale for Y-axis, 1 means not a nuisance at all, 5 means intolerable

Figure 14 Boxplot for nuisance scaling by age. (Hump)

Median Divider

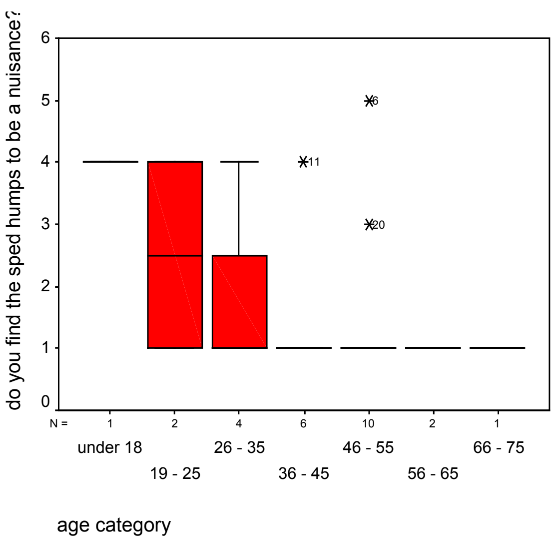
Due to the small number of residents and difficulties in finding them at home, the resident survey on Asylum Avenue has only two records. So we did the analysis of resident and public survey data together.

We found during our survey that, unlike speed humps, peoples' acceptance of the median is more uniform. The average nuisance scale evaluation of this type of traffic-calming device is 1.69, which is much lower than that of humps (2.68).

Age and nuisance scale: First, let us look at the relationship between age and nuisance scale. Table 8 gives detailed information by category and Figure 15 gives a box-plot, which reveals several outliers skewing the scales. The range of values is small, except for two younger age categories (19-25 and 26-35). We can probably attribute the reason to the small sample sizes, which are two and four respectively. As to the other six categories, we can see that nearly all respondents like the medians and plantings.

Table 8 Detailed Nuisance Scaling by Age (Median Divider)

	1 = Not a nuisance > > > > > > 5= Intolerable				
Age\	**1**	**2**	**3**	**4**	**5**
under 18	0	0	0	1	0
19-25	1	0	0	1	0
26-35	3	0	0	1	0
36-45	5	0	0	1	0
46-55	8	0	1	0	1
56-65	2	0	0	0	0
66-75	1	0	0	0	0
above 75	0	0	0	0	0



The scale for Y-axis, 1 means not a nuisance at all, 5 means intolerable.

Figure 15 Boxplot for nuisance scaling by age. (Median divider)

During the survey process, we found that people usually like medians and plantings. Not only because they are useful to slow down traffic but also because of their positive visual effect on the road environment and on improving the livability of the neighborhood. Therefore we can expect that there should be no significant difference in reported nuisance scale between the genders or respondents who have or do not have young children. The results show that this expectation is correct. The median and mean numbers of these categories are basically the same.

Winding Pattern

Public Surveys

Very few respondents were familiar with this street when we did the public survey in a nearby shopping center. To augment this data set we interviewed residents whose homes are located on the street immediately upstream of the winding street, and are thus likely to use the winding street for many trips. Altogether we interviewed 20 respondents for this public survey.

Unfortunately, respondents' answers indicate that the winding pattern used here is not very effective in slowing down traffic. Of all those 20 respondents who answered our survey questionnaires, 13 admitted that they have not changed their speed. Only five who used to drive faster than the speed limit now drive slower than the speed limit. The remaining two have not used the street since the winding pattern was installed.

Superficial examination of the data shows that respondents don't like the winding street pattern. However, taking a closer look at their additional comments, we find that the real objection they hold to the street is that it is too narrow. Of all those seven respondents who express evidently strong negative opinions with respect to the winding pattern, four told us that it is the narrowing that makes them very uncomfortable. Indeed, only three of the 20 respondents told us they dislike the winding pattern itself.

Resident surveys

The overall impression is that residents of St. Charles are very happy with their winding street, although there are still inevitably some objecting voices regarding some short-

shortcoming of them.

We learned that indeed the winding pattern is the product of requests of residents and extensive research conducted by the local government. Before it was installed, some drivers even drove at a speed of about 60 mph (97 km/h). Residents think the reconstruction has been very effective in slowing down traffic because the mean value of the effect response given by the residents was 3.0.

The residents appear to really like this traffic-calming device. The mean of nuisance scaling is 1.7, which shows that hardly any respondents think the pattern is a nuisance.

The winding pattern does not make residents there change their travel habits much. Sixteen out of 20 respondents said they haven't changed their habits at all. Of the remaining four respondents, two indicate that the main factor that caused the change is the one-way feature instead of the winding pattern.

At this location, the relationship between marital status and nuisance is quite evident. Average nuisance estimation scales for married and unmarried respondents are 1.21 and 2.83, respectively. We think that married people are more cautious than unmarried people, thus they are more inclined to accept traffic-calming devices. However, it may be age and other underlying factors that explain part of this difference, too. For example, married people more frequently have children than single people do, and parents may see the need for lower speeds and thereby feel that the experienced nuisance is less annoying.

Integrated Analysis

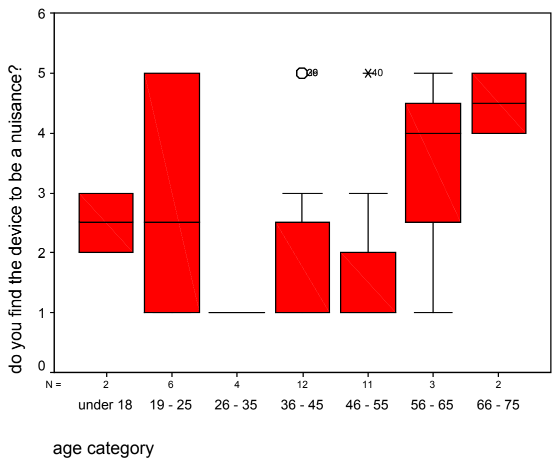
According to the data, there is no significant difference between the opinions of men and women about the level of nuisance of the traffic-calming devices. Females feel a little less annoyed by the winding pattern than men since the average scale for the winding pattern by women is 1.9, and for men is 2.6. The median values are 2.0 and 1.0, respectively. This indicates very diverse opinions among men.

A similar pattern to that of gender also exists in the relationship between the children variable and nuisance scale. The average scaling of respondents who have children and have no children younger than 16 are 1.94 and 2.33 respectively. However, the median values of these two groups are the same.

If we take a look at the relationship between age and nuisance scale, a tendency is seen. The youngest and older respondents don't like the pattern very much. Younger adults and middle-aged respondents are more likely to accept it. Details are listed in Table 9, and the box-plot in Figure 16 depicts this tendency graphically.

Table 9 Nuisance Scaling by Age (Winding Pattern)

	1 = Not a nuisance > > > > > > 5= Intolerable				
Age\	**1**	**2**	**3**	**4**	**5**
under 18	0	1	1	0	0
19-25	3	0	0	1	2
26-35	4	0	0	0	0
36-45	8	1	1	0	2
46-55	8	0	2	0	1
56-65	1	0	0	1	1
66-75	0	0	0	1	1
above 75	0	0	0	0	0



The scale for Y-axis, 1 means not a nuisance at all, 5 means intolerable.

Figure 16 Box-plot for nuisance scaling by age. (Winding pattern)

Positive Opinions

Hump

Some residents were so afraid of having the humps taken away that they refused to answer our survey questions at the beginning. All they would say is that the humps are good. Some residents requested additional humps between the current humps because they find that some drivers will speed up between the existing ones. They want a third one to prevent that.

Median Divider

People usually like medians more than humps because the medians are visually more attractive.

Winding Pattern

Residents themselves asked the town government to install the winding pattern for them to slow down the 'crazy' traffic. Everyone on the street is said to have voted for it.

Negative Opinions

Hump

Residents have several kinds of complaints about the humps. For example, they generate noise when cars hit them or decelerate and accelerate before and after them. One man complained about the yellow color of the sign. One woman who has her living room directly beside the hump complained that drivers usually would look inside her window subconsciously when they slow down for the humps and need not concentrate on driving. One man told us that some aggressive drivers speed up to 65 mph or so to 'fly' over the humps. It is said that especially some young drivers like to use this method to avoid discomfort brought by humps[2]. Drivers passing by have even more complaints about them. The most common opinion is that the humps are too high or too wide. They think that the humps are not designed for the speed limit they are supposed to be for, which means you nearly have to stop completely to pass without any discomfort.

Median Divider

Some respondents think the median obstructs sight distances, especially for cars turning onto and from the street.

Winding Pattern

Some respondents complained about the narrowing of the roadway. Older respondents and women usually felt that it became more difficult to drive here, especially when there already is a car parked on the side of the road.

Conclusion of Connecticut Study

This survey shows that traffic-calming devices are reasonably effective in slowing

[2] Compare Figure 7. Extrapolating the curve for the 3.7-meter hump shows that the discomfort is about 2.0 at a speed of 65 mph (105 km/h). To get a lower discomfort at low speeds, the driver will need to reduce the speed to less than 12 mph (20 km/h)

down traffic and make a friendlier community. Based on the data analysis described above, we find that both residents and passing-by drivers find the traffic-calming devices to be effective to slow down speeds of vehicles. In the resident survey, 73% reported an effectiveness rating of 3, or average. In the public survey, 45 out of 75 who used to drive faster than the speed limit claimed that they now have slowed down to below the speed limit. The overall support rate (defined as the proportion of people who choose 1 or 2 when they were asked about whether the traffic-calming device is a nuisance or not) is more than 50%. If only medians and winding patterns are concerned, the support rate will be above 70%. We believe it would be acceptable to install these two types of traffic-calming devices (median and winding pattern) on the segments of major highways where they pass through town centers.

Up to now, the speed hump seems to be the most commonly used traffic-calming device while also the most controversial one. An arbitrary assumption usually made by engineers is that even if passing-by drivers won't like the humps, residents will like them because they significantly slow down through traffic and bring a safer neighborhood to them. However, the results of our survey reveal that many residents are even more unsatisfied with humps than drivers just passing through. They may object to them for reasons such as noise, aesthetics, or pollution due to extra acceleration and deceleration.

8.3 Attitudes among City Officials

When it comes to people's attitudes, it is important to include the general public as well as city and town engineers, public works directors, fire chiefs, managers of ambulance services, police chiefs and others that are directly affected in how they can serve the citizens of their community. The survey of the general public was covered by the Connecticut study presented in the previous section. The survey of city and town officials focused on twelve municipalities in Maine. Maine is a mostly rural state with only four urbanized areas with more than 50,000 people, but with considerable pedestrian activity in many small towns along rural highways. Many of these towns are not served by limited-access highways and lack bypasses, resulting in lots of traffic through the town centers. The aim with the surveys was to capture the attitudes towards roundabouts, traffic circles, mini-circles, humps, chokers, etc, as well as speed-limiters in vehicles. Rather than using a standardized interview sheet, the attitudes were captured in face-to-face and telephone interviews using a free discussion—but with specific questions to guide the discussion in the desired direction without biasing it towards desired attitudes to specific schemes. The discussions were preceded by a few statements about high speeds not being desirable in sensitive environments and the need to reduce speeds. If that is the premise, how then can speeds best be controlled, not today, but say ten years from today.

It was not hard to get people to agree with the premise that speeds are too high in many built-up areas. In fact many of the respondents brought that up themselves. For example, Public Works Director Frank Higgins of Brewer says, "Today's speed limits are okay. It is compliance that is bad. I get complaints both on major streets and residential." Police Chief Timothy Richards of Norway (Maine) agreed that today's speed limits are reasonable but that compliance is an issue at many locations.

Also, there seems to be an agreement not only that the speeds of the general public should be controlled, but that lower speeds—as long as traffic is moving and/or can pull to the side to let emergency vehicles by—is not a concern for ambulance and fire departments. This is reflected in, for example, a statement by Mr. Pinkham, Fire Lieutenant in Brewer, "Speed reduction is not an issue for fire trucks as long as passage is not blocked. We go at low speeds through signals even when we have a green light. But if congestion is created, then that is bad." An issue brought up by fire chiefs is that a majority of drivers do not stop when an emergency vehicle is coming even if most people do slow down and keep to the curb. There seems to be a consensus among fire chiefs that it would be better if people just stopped "wherever they were." In other words, operators of emergency vehicles think that no speed is typically better than a low speed when trying to predict how to get around these vehicles. Also, as expressed by Steve Gibbons, Chief of Fire for Camden, "Getting stuck behind vehicles traveling at low speeds is more a problem for volunteers of getting to the fire station than for the fire truck with sirens on. There are only two full time fire fighters plus the chief in Camden and fifty-six on call."

Since September 2001, Maine towns can set speed limits on all town roads. Prior to that, Maine Department of Transportation set all speed limits in the state. It is anticipated that several town councils will decide on lowering the speed limit to 15 mph on some of their residential streets. Public works directors and others have a concern of how such limits will be enforced.

There is a general consensus among public works directors and town engineers that physical measures in the roadway are a nuisance, especially for snow-removal crews but also for emergency vehicles. This is expressed by the Bangor Public Works Director Arthur Stockus, "In this climate, speed-reducing measures makes plowing too hard. Rather work with enforcement and/or public campaigns. An in-vehicle speed limiter is an interesting concept, but people would probably find a way around it if instigated and there would be a lot of public resistance to that."

Several other people are of the opinion that in-vehicle speed limiters would never be accepted in North America. Surprisingly, many were of the view that they themselves would appreciate such a system, here represented by John Foster—public works director of Brunswick—who stated, "In-vehicle speed limiters seem like a great idea, to me, but will people ever accept that?" Paul Cartwright, council member of Camden expresses the same thought and so do several ambulance drivers and many of the general public. So, maybe a majority of people would accept such systems, even though they think that a majority of others would not accept it. It was also brought up that intelligent in-vehicle speed limiters may be a good option especially since emergency vehicles easily could be excluded. And as Al Dravidious, Orono Police Chief says, "Humps and bumps punish everyone, not only the speeders. I would be opposed to such measures, especially since they are not safe for emergency vehicles." He would personally also much rather see electronic speed limiters in the vehicles but (like others) has concerns with how to get acceptance for such devices and continues, "Maybe 'stiffening only' gas pedals combined with a light on the roof could become acceptable to people."

To return to physical in-road measures, a few neck-downs have been constructed in Maine towns. A recent one on Maine Street in Brunswick will not be followed by others since the merchants found out that the neck-downs may eliminate a parking space or two, and their opinion seems to be that losing one parking space is the equivalent of a capital offense.

There is strong resistance to humps on arterials for many reasons. One is that the structural integrity of fire trucks may not allow these vehicles do go over such humps even at speeds comfortable to passenger car occupants. Another concern, expressed by among others Orono Fire Chief Lorin LeClair, is that patients on stretchers with potential neck or spinal-core injuries can have their injury severely worsened by such humps. Among the general public of Eastern and Central Maine, there is a view that humps can be used where they are 'needed' such as at grocery stores or school driveways, but that humps are unacceptable on arterials and major collector roads (as if speed-control weren't needed there, probably to a higher degree).

The experience with modern roundabouts is still very limited in Maine. People have in general not very favorable views of the Augusta rotaries and many are afraid that all roundabouts would function in similar ways. However, there are several town engineers who express a clear interest in roundabouts. And, John Foster—public works director of Brunswick—says that residents recently opposed the installation of a new traffic signal on Maine Street and suggested a roundabout for that location. Soon Brunswick may have many traffic-calmed streets. Instead of roundabouts, some town engineers in Maine suggest that all-way stops can be used to reduce speeds. When such all-way stops were put up in Brewer, speeding complaints stopped and the town employees are happy to see that it seems to work, at least in the eyes of the general public.

Narrow lanes and town gates are possible traffic-calming devices on arterials according to many of the interviewed subjects. A question is how effective such measures are, and how bicyclists fare with narrower lanes.

Pedestrian crossing signs placed in the streets seem very effective according to public works directors in Hallowell and Brunswick. It is perceived that they reduce the speed at crosswalks, and several towns now have the policy to leave these signs out all the time except for during snowstorms.

Chief of Police Jerry Hinton, Town of Brunswick, reports that they nowadays have a zero tolerance for issuing warnings and a 5-mph ticket margin and have seen some improvement with respect to speed compliance, at least downtown. However, Chief Hinton continues, "… enforcement must take a back seat to physical design. Maybe 35% to 65% in importance. Bump-outs at crosswalks are important even if a few parking spaces are lost. Traffic islands are also helpful." He also discussed public campaigns and mentioned that in Brunswick, they have distributed lawn signs stating, "Your neighbor asks you to observe the speed limit of 25 mph." He says, "This has more effect than a police car that will not be there tomorrow. The neighbor will be there then too, and will keep the attitude that speeding is wrong…" The Chief also believes that active signs showing "Your speed is …mph" are effective at those exact spots at least for a while after the sign is removed, but that their effectiveness is not very great at other places.

There are people who believe that physical measures as well as speed-limiters may be justified. However, there are also people with very different views. One subject stated, "Enforcement is better than physical measures or in-vehicle speed limiters. Pedestrians should learn to walk on sidewalks rather than in the highways." This person is Fire Chief in a town with a highway straight through the town center with shops on both sides of the street.

8.4 Complementary Discomfort Studies

Additional studies within this project compared the discomfort of passing over speed-humps and speed tables at speeds around 20 km/h (12 mph) to the discomfort of making a sharp turn from one street to another at a similar speed. A scale of 1 to 5 was used for assessing the discomfort. Approximately 25 monitored tours were made on street systems that have such devices. Some of them were done in Connecticut, but the majority were done in Portland, Maine, around Stevens Avenue. The results were that passengers passing over a hump or table experience just slightly higher discomfort than when making sharp turns. Also, this discomfort was roughly the same as that experienced in stop/go conditions at a stop sign, and some subjects experienced the stop as worse. Still, it is reasonable to assume that people accept higher discomforts when they think that a device is necessary or highly warranted, like a stop sign. Many people do not understand that high midblock speeds may compromise safety as much as high speeds through intersections.

9 CONCLUSIONS

When choosing traffic-calming devices for State highways, it must be considered that these roads function not only as neighborhood shopping streets and residential streets but also as thoroughfares and routes for trucks and emergency vehicles. Traffic-calming devices therefore must allow reasonable comfort at posted speeds, which between intersections ought to be at least 20 mph (32 km/h). Today, the allowed speed is seldom less than 25 mph (40 km/h), and top speeds are much higher, but typical average driving speed is often lower than 15 mph (24 km/h), especially through towns with several signalized intersections. Therefore, reduced top speeds do not necessarily lengthen average travel times if roundabouts are constructed at the key intersections.

Currently the typical size of a hump is 12-14 feet (3.6-4.3 m) long and they usually are placed about 600 feet (180 m) apart. The design speed for streets that have humps is typically 25 mph (40 km/h). However, in practice, drivers must slow down to speeds around 10 to 15 mph to pass the humps if they don't want to feel too uncomfortable.

The hump is likely to change traffic distribution under certain circumstances. For example, when there are some streets that are parallel with each other and both have humps, but they are different in geometric features, say, different grades. Our survey then suggests that most drivers apparently prefer the street with the gentler grade.

Instead of extensive use of humps, we recommend the use of gentler speed tables as alternatives. Such speed tables are typically 22 feet in the direction of travel with 6-foot ramps at each end and a 10-foot flat top. This device can accommodate higher through speeds than that of speed humps, and is therefore more suitable to be used on segments of highways. Still, even the speed table becomes uncomfortable at higher speeds, so they do act as effective traffic-calming devices. Before installing, extensive traffic investigations should be conducted in nearby areas to avoid serious negative effects on traffic assignment of the neighborhood network.

The median divider is another widely used traffic-calming device, and it has much better reputation than the hump. At the same time as slowing down through traffic, it also improves aesthetics of the neighborhood community. However, we think that adding objects to the street may increase the chance for vehicles to hit it, either because it narrows the usable width or it reduces sight distances. Accompanying median installation, corresponding measures should be taken into account to remind people that the median exists and to ensure adequate sight distances even with the median plantings.

Winding pattern is one of the traffic-calming devices that reach their goals by changing physical features of the street. In this case, it seems that residents and public users accept this type of traffic-calming device. Indeed, construction of this winding pattern was requested by residents on the studied road. As to public users, some of them said that they have not even noticed that there is a winding pattern there. Visual obstacles give drivers certain pressure to prevent them from speeding. Of course there is also some negative feedback. One major complaint was about the narrowing of the street. Some seniors and women feel it is more difficult to drive especially when there are trucks parked on the street. Parking bays could be included to slightly widen the road. (In our case, the street was changed into a one-way street at the same time as its physical reconstruction.) If the road is kept wide, it is important that the winding is not too gentle. If a driver can proceed through the street at a high speed with low side acceleration, then the speed reduction will be minor.

When starting this project, it was the opinion of the authors that physical traffic calming of arterials would be the best way of achieving speed compliance on arterials through small towns in, for example, New England. We still believe that in the short-run, such measures would be more effective than increased enforcement and/or public campaigns. However, the study of literature, the analysis of crash data from Portland, Maine, and our surveys do not convince us that immediate substantial safety effects are guaranteed unless much more restrictive speed-reducing measures are installed than what public acceptance today will allow. Still, it should be noted that pedestrian safety is improved by traffic calming. The Danish experience from arterial traffic calming computes as a 75% reduction in injured pedestrians, and the Portland, Maine experience is a reduction of 83%, though numbers are so small that the percentages are very uncertain. And these safety advantages must be weighted against disadvantages. There are obvious disadvantages with humps in the roadways of major arteries, not least for emergency vehicles. We also do not want to make the traveling less comfortable for people going at or below desired speeds. Unfortunately, humps do have such negative side effects.

It is our strong belief that we will not be able to get speed compliance from public campaigns and/or enforcement alone. Today, it is not 15% of drivers who are in non-compliance, but rather 85% or more. Speeding is the norm, especially on arterials. Historically, there was a practice followed by many U.S. towns that speed limits should be set at the 85%-ile speed—that only about 15% of the drivers should be considered not able to judge themselves what constitutes a safe speed. However today's cars are so much quieter and more comfortable than vehicles used to be, that 45 mph (72 km/h) nowadays seems like "very slow" to many drivers on any paved, straight road. But crossing a State Highway may be very difficult and dangerous, especially for elderly and very young pedestrians, when vehicles travel at such speeds. One way of achieving speed compliance by 85% of drivers could be to raise the speed limit from 25 mph (40 km/h) on 'urban' arterials to 40 mph (64 km/h) immediately, and then by another 5 mph (8 km/h) every five years or so. Another policy would be to decide that the maximum safe speed on an urban arterial away from crosswalks is, *e.g.,* 30 mph (48 km/h) and at crosswalks and other 'critical' points 20 mph (32 km/h), and make sure that, say, 99% of drivers stay at or below such limits. The only way to achieve that—in our opinion— would be to equip all vehicles with intelligent cruise controls limiting the maximum speed. We acknowledge that such a system would need general acceptance of at least a majority of drivers before it could be adopted. Experiments in Germany and Sweden show that people become more favorable to such in-vehicle speed limiters after they drive vehicles equipped with such systems for a few weeks. We therefore propose, as a conclusion to this project, that such experiments be initiated in the United States in the near future. It is our opinion that a feasible system for experimentation would be one based on a GPS-locator keeping track of the speed limit for the road being traveled, and sending a signal to the computer of the vehicle making the gas pedal almost completely stiff when this speed is exceeded. However, by exerting extra pressure on the gas pedal, the vehicle could be driven just like today. For enforcement reasons, this system could be combined with a light or lights on the vehicle showing that it is driven above the speed limit, and a light on the dash warning the driver as well that this light is activated. This certainly may not be the final speed-limiting system, but a system as described here may be a starting point for experiments.

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Appendix A: State Survey of Traffic Calming

In July of 2001, the following e-mail was sent by Mr. Bruce Ibarguen, State Traffic Engineer for Maine Department of Transportation to the traffic engineers of all the other State agencies.

-----Original Message-----
From: Ibarguen, Bruce [mailto:bruce.ibarguen@state.me.us]
Sent: Tuesday, July 17, 2001 9:20 AM
To: 'aashto_traffic@yahoogroups.com'
Subject: [aashto_traffic]

The University of Maine and Maine DOT are interested in a response to the following:

Dear Colleague:

In the State of Maine, we are discussing the possibilities of using physical traffic calming measures for speed reduction, such as speed humps, neck downs, and roundabouts, in built up areas along state highways. We are interested in any experiences of this from other states. Can you please respond with yes or no (don't know) to the following question:

Is any traffic calming implemented on a State Highway in your state or on any major collector or arterial in any community within your state?

If the answer is yes, please give us the name and address, telephone number, or e-mail address of a person who can provide information about the measures.

Please reply to

Garder@maine.edu and Bruce.Ibarguen@state.me.us

Thank you for your cooperation,

Bruce Ibarguen, State Traffic Engineer for Maine

The responses are shown in the table below. It may be a stretch of the truth to assume that states that did not respond—and therefore are not listed in the table—have not experimented with traffic calming on State Highways, though that is most likely a fair assumption.

Alaska	NO! Kurt Smith [Kurt_Smith@dot.state.ak.us] writes: Alaska has not implemented traffic calming measures on state highways.
Arizona	Arizona DOT has not installed any of these devices for traffic calming on our system. This is mostly a local issue in our state. Contact would be Jim Sparks (602) 262-4435 with the City of Phoenix.
Connecticut	Coughlin, Walter H. [Walter.Coughlin@po.state.ct.us] writes: None on state highways. Some municipalities have plans, but not much built. The city of New London has built two roundabouts on the collector that serves Pfizers new 1,000,000 s.f. research center but the building is not fully occupied so there are no results to report.
Idaho	No, Idaho has not implemented any traffic calming of State highways.
Illinois	Illinois has not used traffic calming measures for speed reduction on State highways. We will be designing and constructing some roundabouts within the next couple of years.
Indiana	NO! information by: Gary C. Bowser, INDOT, Traffic Field Engineer, 317-232-5433, gbowser@indot.state.in.us
Iowa	The only traffic calming we have used on a primary highway in Iowa has been the conversion of 4 lane undivided roadways to 3 lane (TWLTL) roadways. These have been very successful, improved safety, traffic calming with little loss of capacity. We have done these even in the middle of a four lane divided rural corridor when we passed through a small town.--Tom Welch/DOT/StateIA

Kansas	Kansas is using roundabouts. Contact David Church at 785-296-3618. - Mike David Church on Aug 2, 2001: Traffic signals are often the target of improvements needed. Bypasses built today in high numbers. The experience on business does not seem to be bad. People seem too be on balance happy. Roundabouts built to improve safety, and capacity reasons. In urban areas of Kansas people are open to new ideas and support roundabouts. In rural farm communities' people are opposed. They accuse DOT of trying to experiment on them. Some roundabouts (in Manhattan, Kansas; where Kansas State is located. Their president opposed to roundabout, whereas the Dept of Civ Engineering were in favor) were stopped at public hearing/politicians even though DOT and City engineering people in favor. Mini-roundabouts hurt the reputation of roundabouts. So far 10 roundabouts built (only 2 on State Highways) and many under construction. Most on County Roads (collectors) rather than State Highways or Town Streets. For example, 4-way stop with crashes are being converted. They will come to arterials soon. The state is in the process of evaluating the roundabouts. (Professor Gene Russell is evaluating the roundabouts.) The State has never been approached by a city to implement traffic calming on state highways. But we would be open to discuss it, when approached. Also contact Dr. Gene Russell at Kansas State University in Manhattan. Below is Dr. Russell's e-mail address: geno@ksu.edu. Also, for your information is a copy of the KSU Roundabout web-page. It may be of some interest to you as well. http://www.ksu.edu/roundabouts/ If you have any other questions about what Kansas is doing with regard to roundabouts, please don't hesitate to call me at (785) 296-3618. David Church, Senior Traffic Engineer, KDOT, Bureau of Traffic Engineering
Nebraska	Nebraska has not used speed humps, neckdowns or roundabouts solely for speed reduction. We are evaluating use of permanent electronic speed feedback devices in one location. Randy Peters, Traffic Engineer
Nevada	Nevada hasn't used any physical traffic calming devices for speed reduction. We have installed some roundabouts on some state maintained roadways instead of 4-way stops or signals. They have worked well so far where we have used them. At the one location near my house, we don't have the large queue backups during the peak hours that we had with the 4-way stop. I'd be interested in the results of your survey also. Sincerely, Scott L. Thorson, P.E., Traffic Engineering Section Chief, Nevada Department of Transportation, 1263 S. Stewart Street. Carson City, Nevada 89712, Phone: 775)888-7490; Fax: (775)888-7401. E-mail: sthorson@dot.state.nv.us
New Hampshire	The answer to the question regarding "any" traffic calming implemented on state highways in New Hampshire is yes. Keep in mind that the "traffic calming toolbox" is large and there are a number of tools to use. Although a number of communities have added the structural measures listed below (e.g. Nashua and Manchester), the State DOT has relatively little experience other than using the edge lines to define narrow lanes (10 or 11 feet). We have met with the Town of Dublin, west of Manchester, to discuss measures we could take to slow traffic down along a major east/west corridor through town. That may be our first experience with structural traffic calming measures. I would be the primary contact person. My contact information is, William R. Lambert, P.E. (Bill), Traffic Engineer/Administrator, NHDOT Bureau of Traffic, P.O. Box 483, Sheep Davis Road, Concord, New Hampshire 03302-0483, (603) 271-2291, (603) 271-6083 (fax) wlambert@dot.state.nh.us
New Mexico	To date NM has not implemented any physical traffic calming measures on state highways that I am aware of. However, there is a push...perhaps a wave...of public opinion and pressure being applied by various neighborhood groups and communities on the Department to do this very thing. In one case we are in the process of trying to reconstruct NM 14, a scenic byway, defined as a major collector about 50 miles through rolling terrain between Albuquerque and Santa Fe that traverses several small communities. The communities are fighting (very successfully, I might add) to reduce the cross-section (11' lanes with 4' shoulders) and maintain the curvelinier nature of the existing highway. Our normal, AASHTO, standard for a facility with the ADTs we have here would call for 12' lanes with 8' shoulders. As another example, we recently designed a conventional signalized intersection in the Village of Corralles, NM. The intersection met several MUTCD warrants. The community, however, successfully blocked the project and demanded the State investigate a roundabout. This has been done and we have scheduled a public meeting to present our findings. Though I would be somewhat surprised if we actually build the roundabout at this location (due to R/W and operational issues), I believe that construction of a roundabout on a state highway is just a matter of time. Let me know if you'd like more info on either of these projects. – Bob

North Carolina	Ken Ivey, North Carolina's acting State Traffic Engineer, asked me to respond to your aashto_traffic maillist questions. North Carolina at this time does not allow traffic calming devices on our State Highways. This does not include roundabouts, which are installed as traffic control devices at two intersections on the State road network, with at least a dozen in design or construction. Reading a couple of the responses below, we are considering converting some four-lane roads (two lanes in each direction, with a combo. left-thru at intersections) to a three lane (one through lane in each direction, with a center turn lane). As with the roundabouts, we do not consider this action a "traffic calming" measure, but more of a safety concern. The traffic calming "side-effect" of these devices is incidental to the installation, although the subject was discussed during planning (especially for a couple of roundabout locations.) (FYI, North Carolina does not have a county level of street/road responsibility, so the State has that responsibility as well as the traditional State/U.S./Interstate level of responsibility. This means that despite the relatively small physical size of the state, North Carolina has the second largest State maintained road network in the country (behind Texas, by a slim margin.) If you have any questions, or need further information, please do not hesitate to call or e-mail me. Jim Dunlop, Congestion Management Engineer, NCDOT; jdunlop@dot.state.nc.us ; (919) 250-4151
Oregon	Doug Bish ((503)986-3594)is ODOT's Traffic Investigations Engineer and can provide more specifics on your questions. In Oregon we have implemented one roundabout on a state highway with another being contracted for 2002. Plans for others have been proposed. These are typically urban settings. There are efforts underway throughout the state to 'calm' downtowns or main streets where state highways run through. These are typically less obtrusive measures such as pedestrians' bulb-outs, pedestrian refuge islands, streetscaping, lighting, on-street parking, landscaping, wide sidewalks, etc. Redevelopment of businesses is being encouraged with urban redevelopment funds. We have typically not implemented speed bumps, speed humps, chicanes or other more aggressive forms of traffic control on state highways. Much of this has been captured in a document called "Main Street Handbook" produced jointly by Oregon Department of Transportation (ODOT) and the Oregon Department of Land Conservation and Development (DLCD). If you would like a copy I can have one sent by mail.
South Carolina	You requested through AASHTO information from state DOTs about the use of physical traffic calming measures on state roads. South Carolina DOT recently adopted a new guideline on traffic calming. This policy allows local governments to place physical calming devices on state maintained roads that qualify (Functional classification of local residential or minor collector). There are some speed ramps now in place on our roads and others are being planned. I can send you a CD of the guideline for your information if you desire. I would need a mail address for you. Let me know if you need it. I have not sent him my address yet. Also Carol Jones of my staff developed the guideline. She can answer any questions you or your staff may have. Her phone number is 803-737-1050. -- Rick Werts, 803-737-1463 Carol Jones: Used ITE tool box + Oregon guidelines + Canadian Inst of Transportation + a couple of other state guidelines. Mini circles allowed. Narrow chicanes not allowed. Neckdowns allowed if turning radius allows. 14', 3" humps allowed if less than 2000 AADT. If 4000 or less flat hump allowed. 3 or 4 in Greenville. Charlston has numerous requests and will build, and they have on city streets… Liability can become an issue. If due process is followed, liability may not be a problem. Encroachment measure procedure followed. Town pays for installation and maintenance. 4-way stops have been successful in rural areas. Low volume, high speed, even unwarranted very successful, safetywise. In urban areas people compensate speedwise. In rural areas with miles in between that is not an issue. CD sent by mail August 2, 2001
South Dakota	South Dakota Department of Transportation is not using any of the methods described in an attempt to reduce speeds. -- John Adler, Traffic Operations Engineer
Tennessee	The only one (other than old town squares) that I am aware of is a roundabout currently under construction in the City of Chattanooga. It is at the end of a tunnel which would have made signalization difficult to install and sight lines to signal heads would have been obscured. It is on a state route with high traffic. It is being constructed by the City. The City Traffic Engineer is John W. Van Winkle at 423-757-5005. Since it is still under construction, there is no info on how it is working. Michael L. Tugwell, State Traffic Engineer

Wiscon-sin	Wisconsin has not deployed any physical "traffic calming" measures for speed control on our State Highways as yet. We are considering and will likely install roundabouts, though, at about 6 locations on our STH system within the next few years. There are several local road roundabouts that we have been watching. The contact to discuss roundabouts is Pat Fleming (608-266-8486) from our Bureau of Highway Development. I have cc'd Pat so you have his e-mail as well. Even though we have not done anything on state highways with speed humps, neck downs etc, I think our position would be that it would depend on the character of the traffic. If the traffic would be primarily local, then we could give a closer look than if there was considerable through traffic on the route in question. We would also look at alternative routes that traffic might attempt to use or could use to avoid the highway with the traffic calming measures. As you know there are a zillion other considerations, such as the impact on emergency vehicle traffic, trucks, people with disabilities or physical conditions that could be jarred by the humps in particular, etc, etc. I would be interested in the results of your evaluations. Conversation with Pat Fleming (July 23, 2001) clarified: No other speed-reducing measures besides round-abouts and refuge islands used on state roads yet but angled parking being reconsidered. When it comes to roundabouts, 4 to 5 more planned. At least one of the constructed ones has multiple lanes. Leif Ourston and Brian Ray of Kittleson and Associates involved in design. The public opinion with respect to roundabouts is almost non-existent, except where they are built. And among drivers who have been to Massachusetts who are very skeptical of circular intersections.
Wyoming	We haven't used any physical devices to hold speeds down. Mike Gostovich, State Traffic Engineer, Wyoming

Appendix B: Survey forms used in Storrs

Resident Survey (Storrs)

1. How long have you lived in this house?
☐ 1-6 months ☐ 6 months-1 year ☐ 1 year-2 years
☐ 2-5 years ☐ 5-10 years ☐ more than 10 years
2. What is your age?
☐ under 18 ☐ 19-25 ☐ 26-35 ☐ 36-45 ☐ 46-55
☐ 56-65 ☐ 66-75 ☐above 75
3. Do you have children younger than 12?
☐ Yes ☐ No
4. Do you work or go to school at UConn?
☐ Work ☐ School ☐ Both ☐ Neither
5. Do you find the recently installed speed humps on your street to be a nuisance?
(1= not a nuisance, 5=intolerable)
☐ 1 ☐ 2 ☐ 3 ☐4 ☐5
6. Have you found the speed humps to be effective for reducing the speed of through traffic? (1=not effective, 5= extremely effective)
☐ 1 ☐ 2 ☐ 3 ☐4 ☐5
7. Have you changed your travel habits as a result of having the humps?
(1=not at all, 5= major changes)
☐ 1 ☐ 2 ☐ 3 ☐4 ☐5
If you checked 5, please tell us briefly how you have changed your travel habits
8. Feel free to add additional comments about the speed humps.

Public Survey (Storrs)

1. Do you work or study at UConn? ☐Yes ☐No
2. Are you familiar with the recently installed speed humps on Westwood and Eastwood Roads?
☐ Yes ☐ No
If you answered "no" to either of these questions, we do not need you to answer any more questions. Thank you for your time.
3. What is your age? ☐ under 18 ☐ 19-25 ☐ 26-35 ☐ 36-45 ☐ 46-55
☐ 56-65 ☐ 66-75 ☐above 75
4. Do you find these speed humps to be a nuisance? (1= not a nuisance, 5=intolerable)
☐ 1 ☐ 2 ☐ 3 ☐4 ☐5
5. Which of the following best describes your driving speed on these streets before and after the humps were installed?
☐ I have always driven on these streets at 25 mph, so I have not changed my habits due to the presence of the humps.
☐ I have always driven on these streets faster than 25 mph, and installing the humps has not changed my habits.
☐ Before the bumps were installed I drove on these streets faster than 25 mph, but since they were installed I drive slower than 25 mph.
☐ Other: ______________________________
6. How often did you use the streets mentioned above BEFORE the speed humps were installed?
☐ never ☐ occasionally ☐ at least once per month
☐ at least once a week ☐ every day
7. How often have you been using these same streets SINCE the speed humps were installed?
☐ never ☐ occasionally ☐ at least once per month
☐ at least once a week ☐ every day
8. Feel free to add additional comments about the speed humps.

Appendix C: Survey forms used in West Hartford

Resident Survey (Whetten St., West Hartford)
1. You are a: ☐ Male ☐ Female
2. How long have you lived here?
☐ 1-6 months ☐ 6 months-1 year ☐ 1 year-2 years
☐ 2-5 years ☐ 5-10 years ☐ > 10 years
3. What is your age?
☐ under 19 ☐ 19-25 ☐ 26-35 ☐ 36-45 ☐ 46-55
☐ 56-65 ☐ 66-75 ☐above 75
4. Are you married? ☐ Yes ☐ No
5. Do you have children younger than 16? ☐ Yes ☐ No
6. Do you find the recently installed traffic-calming device on your street to be a nuisance? (1= not a nuisance, 5=intolerable) ☐ 1 ☐ 2 ☐ 3 ☐4 ☐5
7. Have you found the device to be effective for reducing the speed of through traffic? (1=not effective, 5= extremely effective) ☐ 1 ☐ 2 ☐ 3 ☐4 ☐5
8. Have you changed your travel habits as a result of having the traffic-calming device?
(1=not at all, 5= major changes) ☐ 1 ☐ 2 ☐ 3 ☐4 ☐5
If you checked 5, please tell us briefly how you have changed your travel habits
9. Feel free to add additional comments.

Public Survey (West Hartford)
1. Do you live in West Hartford? ☐Yes ☐No
2. Are you familiar with any of the following streets and the indicated features? Please check the street and feature you are most familiar with.
☐ Speed humps on Whetten Road ☐ Winding pattern on St. Charles Street
☐ Newly installed median and plantings on Asylum Avenue
☐ I am not familiar with any of these streets and features
If you selected the last box, we do not need you to answer any more questions. Thank you for your time.
3. How often do you use the street?
☐ never ☐ occasionally ☐ at lease once per month
☐ at least once a week ☐ everyday
If you selected 'never', we do not need you to answer any more questions. Thank you for your time.
4. You are a: ☐ Male ☐ Female
5. What is your age? ☐ under 19 ☐ 19-25 ☐ 26-35 ☐ 36-45 ☐ 46-55
☐ 56-65 ☐ 66-75 ☐above 75
6. Do you have children younger than 16? ☐ Yes ☐ No
7. Do you find this device to be a nuisance? (1= not a nuisance, 5=intolerable)
☐ 1 ☐ 2 ☐ 3 ☐4 ☐5
8. Which of the following best describes your driving habit before and after the device was set up?
☐ I have always driven on these streets at 25 mph, so I have not changed my habits due to the presence of the street and indicated features.
☐ I have always driven on these streets faster than 25 mph, and installing the indicated devices has not changed my habits.
☐ Before the indicated devices on the street were installed I drove on these streets faster than 25 mph, but since they were installed I drive slower than 25 mph.
☐ Other:____
9. How often did you use the streets mentioned above BEFORE the devices were installed? ☐ never ☐ occasionally ☐ at least once per month ☐ at least once a week ☐ every day
10. Feel free to add additional comments.