Impacts of Traffic Calming

REID EWING
Fehr & Peers Associates, Inc.
3685 Mt. Diablo Blvd.
Lafayette, CA 94549
r.ewing@fehrandpeers.com
or
Surface Transportation Policy Project
1100 17th St., NW, 10th Floor
Washington, D.C. 20036
rewing@transact.org

ABSTRACT

This paper quantifies the kinds of impacts resulting from traffic calming measures of various types. Descriptive statistics on speed, volume, and collision changes following traffic calming are derived from hundreds of before-and-after studies. Using the same data sets, impact models are estimated. While impacts are case-specific, traffic calming measures generally have the desired effect of reducing speeds, volumes, and collisions.

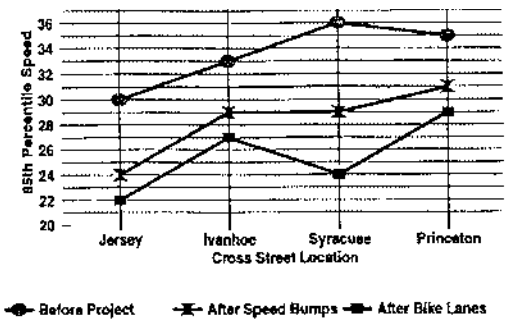
INTRODUCTION

This paper is about impacts of various types resulting from different traffic calming measures. To the extent possible, the impacts of different measures are quantified and impact models are estimated for use by traffic managers.

This research is part of a national study of traffic calming for the Institute of Transportation Engineers (ITE) and Federal Highway Administration (FHWA). The study's principal work product, *Traffic Calming State-of-the-Art* (SOA), includes a chapter on impacts of traffic management measures generally, including speed enforcement and education activities, traffic regulatory measures, and psycho-perception measures (*1*). The SOA report covers a range of traffic calming impacts—including impacts on crime, property values, street life, and noise. In this paper, the focus is on speed, volume, and safety impacts of traffic calming measures only, defined in the SOA report as *changes in street alignment, installation of barriers, and other physical measures to reduce traffic speeds and/or cut-through volumes, in the interest of street safety, livability, and other public purposes. Volume control measures* use barriers to block traffic in some direction, thereby intentionally diverting it to alternate routes. Speed control measures use changes in alignment and roadway narrowing to simply slow traffic along a route.

Practical Value of Impact Analysis

Portland, Oregon's North Ida Avenue project illustrates the practical value of impact analysis. The first phase of the project installed 14-foot speed humps at three locations



Source: Bureau of Traffic Management, "N Ida Avenue Neighborhood Traffic Management Project—Final Report," City of Portland, OR, February 1996.

FIGURE 1 85th percentile speeds before and after traffic calming on N. Ida Avenue (Portland, Oregon).

and chokers (curb extensions) at two locations. These were followed by the narrowing of travel lanes to make room for bicycle lanes.

As shown in Figure 1, 85th percentile speeds declined by 4 to 7 mph with first phase improvements, and by another 2 to 5 mph in the second phase. This brought 85th percentile speeds down to the speed limit of 25 mph at certain locations, and close to it at others. Daily traffic volumes also dropped, by an average of 130 vehicles per day (vpd). Under Portland's diversion policy, traffic increases of up to 150 vpd are deemed acceptable on parallel local streets. In this case, diverted traffic was within the city's policy limits. Also, speed measurements on parallel streets showed no increase, something that often accompanies diversion.

IMPACTS ON SPEEDS

Hundreds of before-and-after studies were collected for the ITE/FHWA study. These individual studies have been used to generate summary statistics on speed impacts by type of measure. Three measures of impact are summarized in Table 1—average 85th percentile speed after treatment, average absolute change in 85th percentile speed from before to after treatment, and average percentage change in 85th percentile speed from before to after treatment. Standard deviations from these averages are also presented in Table 1 to give some idea of the variability of results across studies. Of all traffic calming measures, speed humps have the greatest impact on 85th percentile speeds, reducing them by an average of more than 7 mph or 20 percent. Among speed control measures, raised intersections and narrowings have the least impact. Interestingly, half closures, a volume control measure, have an impact on speeds comparable to speed tables.

One enormous caveat: Rarely in before-and-after studies is it made clear where speed measurements were taken. Occasionally a study will report "midpoint" or "midblock" speeds, but since the spacing of slow points or the length of blocks is unknown, the exact location of measurements is also unknown. The after-speeds may be 100 feet from slow points, 200 feet, or some other distance. Obviously, where the measurement is taken has a profound effect on the result, since motorists decelerate as they approach slow points and accelerate as they depart them. Summary statistics of this sort provide, at best, ballpark estimates of impacts.

TABLE 1 Speed Impacts of Traffic Calming Measures

	Sample Size	Average Speed After Traffic Calming (standard deviation from the average)	Average Change in Speed with Traffic Calming (standard deviation from the average)	Average % Change in Speed with Traffic Calming (standard deviation from the average)
12' Humps	179	27.4 mph (4.0 mph)	-7.6 mph (3.5 mph)	-22% (-9%)
14' Humps	15	25.6 (2.1)	-7.7 (2.1)	-23 (6)
22' Tables	58	30.1 (7.7)	-6.6 (3.7)	-18 (8)
Longer Tables	10	31.6 (2.8)	-3.2 (2.4)	-9 (7)
Raised Intersections	3	34.3 (6.0)	-.3 (3.8)	-1 (10)
Circles	45	30.2 (4.3)	-3.9 (3.2)	-11 (10)
Narrowings	7	32.3 (2.8)	-2.6 (5.5)	-4 (22)
One-Lane Slow Points	5	28.6 (3.1)	-4.8 (1.3)	-14 (4)
Half Closures	16	26.3 (5.2)	-6.0 (3.6)	-19 (11)
Diagonal Diverters	7	27.9 (5.2)	-1.4 (4.7)	-0 (17)

Also, the exact date of measurement is seldom known. The “before” measurement may be one month or three years before installation, the “after” measurement one week or two years afterward. The exact time of measurement may affect results due to the natural growth of traffic and the tendency of travelers to adjust to the new measures. Results from Austin suggest that effects grow over time. Results from Bellevue suggest the opposite. The sheer number of studies precluded any follow-up with jurisdictions to acquire more complete information.

A final caveat: While sample sizes for some measures are large, and sample averages are thus likely to be close to true averages by virtue of the *law of large numbers*, sample sizes for other measures are minuscule. Our sample includes 179 studies of 12-foot humps, but only 3 studies of raised intersections. The sampling error is accordingly many times greater for raised intersections than for 12-foot humps.

Determinants of Traffic Speed

Speed impacts of traffic calming measures depend primarily on geometrics and spacing. Geometrics determine the speeds at which motorists travel through slow points. Spacing determines the extent to which motorists speed up between slow points.

The effects of geometrics and spacing are captured in Figures 2 and 3, prepared by Portland's Bureau of Traffic Management. Fourteen-foot speed humps are used on local streets; 22-foot speed tables (flat-topped humps) are used on neighborhood collectors and local streets serving as transit routes. Before they were traffic calmed, streets treated with 14-foot speed humps had 85th percentile speeds averaging 32 mph. After traffic calming, 85th percentile speeds fell to about 21 mph at the humps themselves, 26 mph a hundred feet upstream, and 25 mph one hundred feet downstream. Streets treated with 22-foot speed tables originally had 85th percentile speeds averaging 40 mph. After traffic calming, 85th percentile speeds fell to 27 mph at the tables themselves, 33 mph 100 feet upstream, and 30 mph 100 feet downstream.

Modeling Midpoint Speeds

For 58 streets in 10 communities, 85th percentile speeds before traffic calming, 85th percentile speeds at midpoints after traffic calming, and spacing of slow points are known. Combined with known crossing speeds at slow points themselves, these are all the data required to estimate speed models. For traffic calming measures in this sample, 85th percentile speeds crossing the slow points are approximately:

- 19 mph at 12-foot speed humps,
- 22 mph at 14-foot speed humps,
- 24 mph at 22-foot speed tables with straight ramps, and
- 27 mph at 22-foot speed tables with parabolic ramps.

Partial correlation analysis showed that midpoint speeds after treatment are related to speeds before treatment, speeds at the slow points themselves, and spacing of slow points. Indeed, midpoint speeds are significantly related to each of these variables, controlling for the others (at the .001, .003, and .001 levels, respectively). To determine the form of the relationship, midpoint speeds after treatment were modeled using nonlinear regression and testing different functional forms, reflecting different assumptions about driver deceleration and acceleration between slow points. It had been assumed that the midpoint speed would equal the 85th percentile speed at the slow points themselves when slow points are closely spaced, and would rise asymptotically toward the 85th percentile

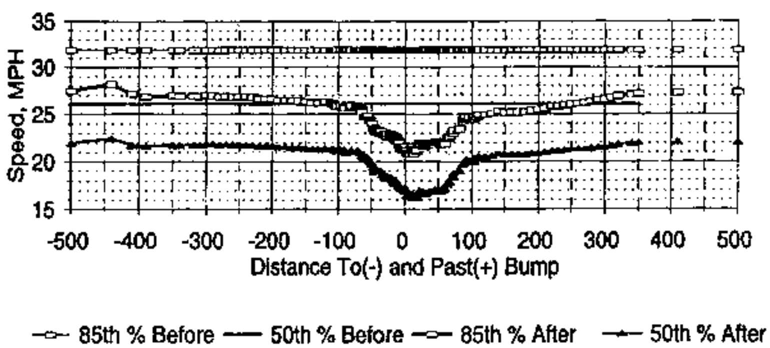


FIGURE 2 Speed profile for a 14-foot hump (Portland, Oregon).

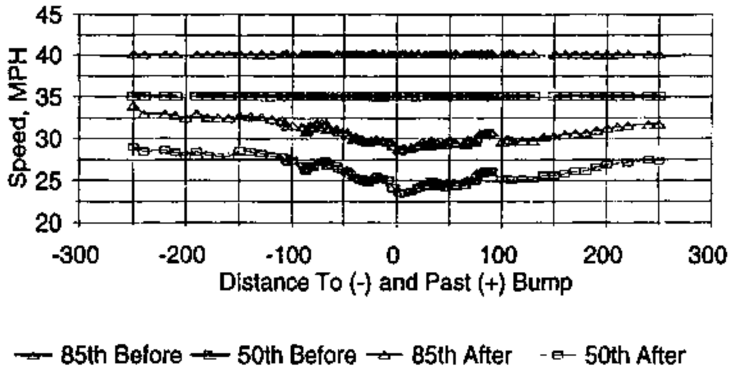


FIGURE 3 Speed profile for a 22-foot table (Portland, Oregon).

speed of the street (before any traffic calming) as slow points become widely spaced. The 85th percentile speed of the street is a function of street width, curvature, fronting land uses, etc., which would continue to limit speeds even with widely spaced slow points.

As first estimated, no functional form seemed to fit the data. The reason, evident from the speed profiles in Figures 2 and 3, is that even with wide spacing of slow points, speeds after traffic calming do not rise to precalming levels. Thus, functions were reestimated, again using nonlinear regression, but now assuming that speeds would rise only part of the way from the speed at slow points to the speed of the street without treatment (as in Figure 4).

For this sample of streets, midpoint speeds rise as spacing increases, reaching 90 percent of their maximum value at a spacing of 600 feet. For this particular sample, with slow points spaced anywhere from 218 to 1,410 feet apart, midpoint speeds rise only 56 percent of the way back to pretreatment levels.

The best-fit curve explains 67 percent of the variation in the dependent variable, the dependent variable being the difference between midpoint speed and speed at the slow

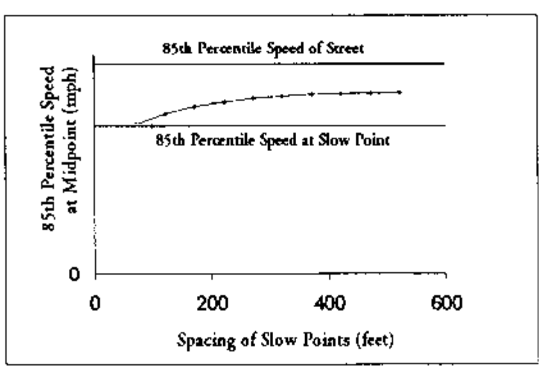


FIGURE 4 Exponential curve relating midpoint speed to spacing (best fit).

point. Given data on speeds before traffic calming, spacing of slow points, and speeds at slow points, traffic managers can predict midpoint speeds with some confidence.

IMPACTS ON TRAFFIC VOLUMES

The effectiveness of traffic calming measures is also judged by impacts on traffic volumes. Volume impacts are much more complex and case-specific than are speed impacts. They depend on the entire network of which a street is a part, not just the characteristics of the street itself. The availability of alternate routes and the application of other measures in areawide treatments may have as large an impact on volumes as do the geometrics and spacing of slow points.

In particular, volume impacts depend fundamentally on the split between local and through traffic. This split also affects speeds, but to a lesser degree. Traffic calming measures will not affect the amount of locally bound traffic unless they are so severe or restrictive as to “degenerate” motor vehicle trips. The concept of degeneration is a relatively new one; we are just beginning to understand how raising the generalized costs of motor vehicle travel can suppress trips. With rare exceptions, traffic calming measures in the United States are unlikely to be strong enough to affect motor vehicle trip rates. What traffic calming measures may do instead is to reroute nonlocal traffic.

Hundreds of before-and-after studies have been tapped to generate summary statistics on volume impacts. Two measures of impact are summarized in Table 2—average absolute change in daily traffic from before to after treatment, and average percentage change in daily traffic from before to after treatment. Standard deviations from these averages are also presented in Table 2 to give some idea of the variability of results across studies. As expected, the largest volume reductions occur with street closures and other volume control measures. However, significant reductions also occur with humps and other speed control measures. The distinction between volume controls and speed controls becomes somewhat blurred in practice.

The same caveats apply to volume impacts as to speed impacts previously. Sample sizes are very small for some traffic calming measures. Also, results depend on where measurements are taken, volume impacts being attenuated by intervening intersections. For example, volumes in the same block as diagonal diverters decline by an average of 45 percent after installation. Volumes a block away, with an intervening intersection, decline by less than half that percentage.

Determinants of Traffic Volumes

Volume impacts of traffic calming measures depend on the availability and quality of alternate routes. This much is clear a priori.

For streets calmed with street closures, diverters, and other volume control measures, impacts would also be expected to depend on which movements are blocked along a stretch of road or at an intersection. A full closure blocks through trips in both directions and should have the greatest impact. A half closure blocks through movement in only one direction and should have an impact about half that of a full closure (discounting trips with a trip end on a particular street—they will be unaffected). A diagonal diverter blocks two out of three movements at an intersection; assuming equal before-volumes on

TABLE 2 Volume Impacts of Traffic Calming Measures

	Sample Size	Average Change in Volume with Traffic Calming (standard deviation from the average)	Average % Change in Volume with Traffic Calming (standard deviation from the average)
12' Humps	143	-355 vpd (591)	-18% (24%)
14' Humps	15	-529 (741)	-22 (26)
22' Tables	46	-415 (649)	-12 (20)
Circles	49	-293 (584)	-5 (46)
Narrowings	11	-263 (2178)	-10 (51)
One-Lane Slow Points	5	-392 (384)	-20 (19)
Full Closures	19	-671 (786)	-44 (36)
Half Closures	53	-1611 (2444)	-42 (41)
Diagonal Diverters	47	-501 (622)	-35 (46)
Other Volume Controls	10	-1167 (1781)	-31 (36)

each approach to the intersection, the impact should be more than that of a half closure but less than that of a full closure.

For street traffic calmed with speed humps, traffic circles, and other speed control measures, volume impacts would be expected to vary with the degree of speed reduction. Route choice depends on relative travel time, and a route that is traffic calmed becomes less attractive relative to alternate routes. How traffic calming of one roadway link affects relative travel time for an entire trip, end-to-end, is impossible to say without detailed origin-destination data. But there should be some impact on link volumes.

Examples from Bellevue, Washington, illustrate the above principles. SE 63rd Street and 162nd Avenue SE were both treated with 12-foot humps. Hump spacing is comparable, and impacts on speed are nearly the same. But SE 63rd Street (Figure 5) has no parallel route available to through traffic, and 162nd Ave SE (Figure 6) has a good alternate route available. Before-and-after studies show an increase in traffic on SE 63rd Street, and a sizable decrease on 162nd Ave SE (see Table 3).

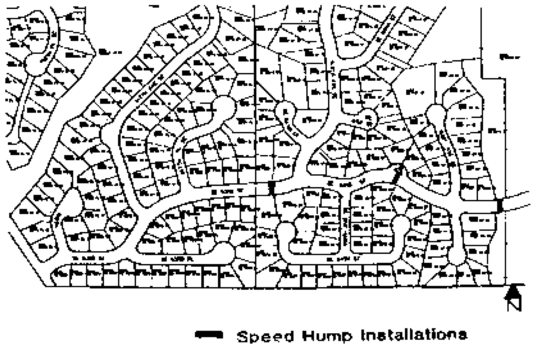


FIGURE 5 SE 63rd Street with no parallel route (Bellevue, Washington).

Somerset Drive in Bellevue was initially treated with 12-foot humps of 3-¾ inch height spaced an average of 150 feet apart. Speed reduction and annoyance were about as great as they get with speed humps. After many complaints from residents, the humps were reinstalled at a height of 3 inches and average spacing of 340 feet. When first treated, Somerset Drive saw its daily traffic volumes drop by a third, with significant diversion to parallel local streets. When the number and height of humps were reduced, daily volumes nearly returned to their pretreatment levels (see Table 4).

Modeling Volume Impacts

Given origin-destination data for trips on the local street network, and given estimates of link speeds after treatment, it should be possible to predict the volume impacts of traffic calming measures using a traffic assignment program that seeks the path with the minimum travel time for each trip. The fact that this has never been done (as far as can be determined) hints at the difficulty of doing so.

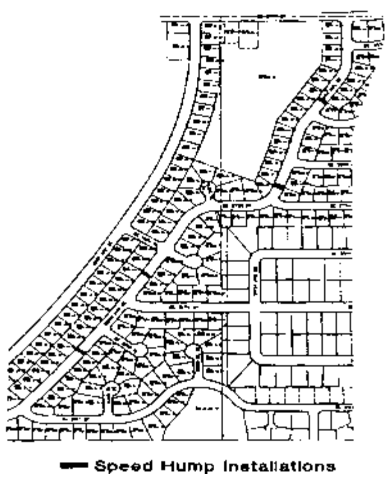


FIGURE 6 162nd Avenue SE with a parallel route (Bellevue, Washington).

TABLE 3 Comparable Treatments with Different Results (SE 63rd St. and 162nd Ave., SE—Bellevue, Washington)

	Measures	Speed Change	Volume Change
SE 63rd Street	12' humps spaced 500' apart (average)	36 ≥ 25 mph	2,456 ≥ 2,593 vpd
162nd Avenue SE	12' humps spaced 580' apart (average)	37 ≥ 27 mph	1,472 ≥ 1,071 vpd

Short of developing or testing traffic assignment software, the most that could be accomplished in this study was to estimate simple statistical models using before-and-after data. A modeling technique known as multiple classification analysis (MCA) was used. MCA is related to analysis of variance, post-processing the latter's results. It is akin to (though much tidier than) multiple regression analysis using dummy variables.

Different models were estimated for volume and speed control measures, in keeping with the different concepts advanced in the previous subsection, "Determinants of Traffic Volumes." In both models, the dependent variable was the percentage reduction in traffic volume and the independent variable was the type of traffic calming measure. For volume control measures, a covariate was tested, that being how far (in blocks) from the measure that traffic counts were taken. For speed control measures, the covariate was the percentage reduction in speed achieved with a particular measure.

MCA results for volume control measures are presented in Table 5. Volume controls categorically reduce traffic volumes by about 39 percent. This figure applies to the entire sample, disregarding the type of measure or number of blocks away counts were taken. As expected, full closures cause the greatest reduction in traffic volumes. Full closures categorically reduce traffic volumes by an additional 5 percent beyond the grand mean. Half closures reduce traffic volumes by an additional 3 percent beyond the grand mean, while other volume controls have less impact on volumes than the grand mean. Each additional block from a traffic calming measure lessens the impact on traffic volumes by 5 percent.

Given the tremendous variation in impacts from application to application, none of the impacts just cited are statistically significant. The differences among measures, while apparently large, are not large enough to be significant at the .05 probability level.

TABLE 4 Volume Changes in Response to Treatments (Somerset Drive—Bellevue, Washington)

	Measures	Speed Changes	Volume Changes
Initial Design	12' x 3-3/4" humps spaced 150' apart	39 ≥ 22 mph (midpoint) ≥ 14 mph (at humps)	795 ≥ 541 vpd
Redesign	12' x 3" humps spaced 340' apart	22 ≥ 27 mph (midpoint) ≥ 23 mph (at humps)	541 ≥ 746 vpd

TABLE 5 Volume Impact Models: Volume Control Measures

Grand Mean % Volume Change -39%	
Significance Levels	
Type of Measure	.71
Blocks from Measure	.16
Deviations from the Grand Mean (adjusted for the covariate)	
Full Closures (19 cases)	-5%
Half Closures (53 cases)	-3%
Diagonal Diverters (27 cases)	5%
Other (8 cases)	8%
Coefficient of the Covariate	
Blocks from Measure	+5.2

MCA results for speed control measures are presented in Table 6. Speed control measures categorically reduce traffic volumes by 15 percent. This figure applies to the entire sample, disregarding the type of measure and its impact on speed. The percent of reduction in traffic volume is weakly related to the percent of reduction in speed. The value of the coefficient, 0.2, implies that traffic volumes are inelastic with respect to traffic speeds. All else being equal, a 10 percent drop in speed will cause a 2 percent drop in volume.

The type of measure employed is significant, beyond whatever effect it may have on operating speed. Humps categorically reduce traffic volumes by an additional 5 percent beyond the grand mean. This is presumably due to the rocking motion they produce at low speeds and jarring impact they have at high speeds. Speed tables and circles, which produce less discomfort, have less effect on traffic volumes.

IMPACTS ON COLLISIONS

Perhaps the most politically consequential impacts of traffic calming are in the area of safety. By slowing traffic, eliminating conflicting movements, and/or sharpening drivers' attention, traffic calming may result in fewer collisions. Due to lower speeds, collisions may be less serious when they occur. What makes safety impacts so politically consequential is the fact that opposition to traffic calming is based principally on safety concerns, concerns related to emergency response.

Seattle's success in implementing traffic calming measures, over many years with less controversy than elsewhere, may be due to its public emphasis on traffic safety. It is hard to go head-to-head with the fire chief when he is threatening delayed response to fires and medical emergencies and you, the engineer or planner, can only offer a nicer street environment. It is easier when you can argue one safety impact versus another.

Faced with budget cuts in 1996, the Seattle Transportation Division resumed its accident analyses and reiterated safety as a departmental priority. Savings in property and casualty losses were estimated to be in the millions of dollars each year (see Table 7). The traffic calming program was spared the budget ax.

Outside the United States

Recently, the Insurance Corporation of British Columbia published a report entitled *Safety Benefits of Traffic Calming* (*2*), in which 43 international case studies are summarized. Among the 43, collision frequencies declined by anywhere from 8 to 100 percent. Apparently in no case did collisions increase with traffic calming.

Traffic circles and chicanes had the most favorable impacts on safety, reducing collision frequency by an average of 82 percent (see Figure 7). It is easy to see why circles might have this effect. They are located at intersections, where a disproportionate number of traffic collisions occur. Circles not only slow traffic on the approaches but reduce the number of potential conflict points within the intersection from 21 to just 8.

It is harder to understand why chicanes would have such a favorable impact on safety. Perhaps it is due to the heightened attention to driving that accompanies the relatively complex maneuver of negotiating an s-curve. It was not clear from the Insurance Corporation's report whether the chicanes studied were one- or two-lane slow

TABLE 6 Volume Impact Model—Speed Control Measures

Grand Mean % Volume Change -15%	
Significance Levels	
Type of Measure	.001
% Speed Reduction	.33
Deviations from the Grand Mean (adjusted for the covariate)	
Humps (144 cases)	-5%
Tables (56 cases)	1%
Circles (40 cases)	1%
Other (22 cases)	6%
Coefficient of the Covariate	
% Speed Reduction	0.2

TABLE 7 Cost Savings Due to Accident Reduction (Seattle, Washington)

	Accidents Prevented (1991-1995)	Cost per Accident	Cost Savings 1991-1995
Non-Injury Accidents	273	$6,500	$1,774,500
Injury Accidents	277	$30,000	$8,310,000
All Accidents	550		$10,084,500

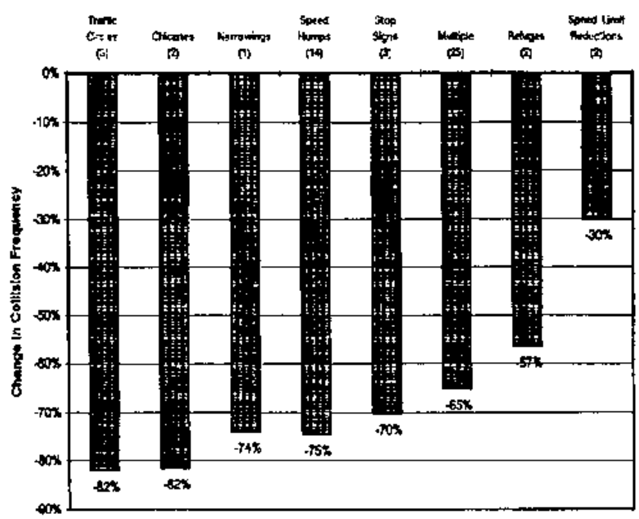
Source: Transportation Division. Engineering Department, City of Seattle.

points. If one-lane slow points, driver attention would be further heightened by the narrow paved width and the potential for conflict with opposing traffic.

In the international survey, humps were almost as effective as circles and chicanes, achieving an average collision reduction of 75 percent. This is counterintuitive. While humps slow traffic, they also create wide variations in speed within the traffic stream. Some vehicles slow down more than others, or slow down sooner than others, etc. Variation in speed, as much as speed itself, is a cause of collisions. For safety impacts of other measures, including some that fall outside the SOA report's definition of traffic calming, see Figure 7. Note that physical measures outperform regulatory measures in this international survey.

Within the United States

Before-and-after studies of collisions in featured communities are summarized in the SOA report. Results are less favorable than the international experience would suggest. In most cases the number of collisions went down or stayed the same, but exceptions appear frequently.



Source: E. Geddes et al., *Safety Benefits of Traffic Calming*, Insurance Corporation of British Columbia, Vancouver, British Columbia, 1996, p. 38.

FIGURE 7 Average reduction in collisions by measure.

The problem is, in part, a statistical one. Traffic calming in the United States is largely restricted to low-volume residential streets. Collisions occur infrequently on such streets to begin with, and any systematic change in collision rates tends to get lost in the random variation from year to year. This limits our confidence in drawing inferences about safety impacts of traffic calming.

A difference-of-means test for paired samples was used to check for significant changes in collision frequencies after traffic calming (see Table 8). The test was applied to the entire sample and to subsamples of different traffic calming measures. The test was also applied to the subsample of measures for which before-and-after traffic volumes are available, adjusting collision frequencies after traffic calming for changes in traffic volumes and hence changes in exposure. For the sample as a whole, collisions decline to a very significant degree after traffic calming (the difference being statistically significant at the .001 probability level). Adjusting for changes in traffic volumes, and dropping cases for which volume data are not available, collisions decline to a less significant degree (but still statistically significant at the conventional .05 level). This drop in statistical significance has as much to do with the exclusion of Seattle circles (with their amazing safety record) as with the adjustment for lower traffic volumes after traffic calming.

As for individual traffic calming measures, all reduce the average number of collisions on treated streets, but only 22-foot tables and traffic circles produce differences that are statistically significant. Including Seattle data, circles are by far the best performers. It is curious that safety impacts of traffic calming would be less favorable in the U.S. than elsewhere. Is it a function of roadway geometrics, driving habits, building setbacks, traffic volumes, or something else? One possible explanation is that European and British traffic calming treatments are more intensive and more integrated with their surroundings than U.S. treatments. Three illustrated volumes—one continental European, one British, and one a mix—clearly demonstrate this point (*3–5*). Hardly a treatment pictured or described has only one type of measure in place; most make use of two or three at a single slow point to calm traffic intensively. Reported speeds drop on average by almost 11 mph or 30 percent in the British sample, compared to under 7 mph or 20 percent for U.S. studies collected for the SOA report.

TABLE 8 Safety Impacts of Traffic Calming Measures

	Number of Observations	Average Number of Collisions Before/After Treatment	% Change in Collisions Before≥After Treatment	t-statistic (significance level—two-tailed test)
12' Humps	49	2.7/2.4	-11%	-0.8 (.41)
14' Humps	5	4.4/2.6	-41%	-1.6 (.18)
22' Tables	8	6.7/3.7	-45%	-4.1 (.005)
Circles				
Without Seattle	17	5.9/4.2	-29%	-2.2 (.04)
With Seattle	130	2.2/.6	-73%	-10.8 (.001)
All Measures				
Without adjustments	192	2.6/1.3	-50%	-8.6 (.001)
With adjustments	42	3.8/3.0	-21%	-2.3 (.04)

It is also curious that Seattle's experience with traffic circles is so much more favorable than elsewhere. One reason may be that Seattle selects traffic calming projects largely on the basis of collision frequency, which could bias results in a statistical sense. Another reason may be that Seattle is traffic calming low-volume residential streets that have a safety problem only because of Seattle's extensive street grid. Elsewhere, circles tend to be used at higher volume intersections that carry more through traffic. A third reason may be that Seattle data relate specifically to intersections, while other places sometimes report collisions for roadway segments including the intersections. The effect of the circles would be diluted in the latter case.

ACKNOWLEDGMENT

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