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Effectiveness of traffic management in Salt Lake City, Utah

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Abstract

Problem: The effectiveness of speed humps, 14 ft (4.3 m) wide by 3.5 in (8.9 cm) high, and tables, 22 ft (6.7 m) wide, on 12 streets in Salt Lake City, Utah was investigated. Mean and 85th percentile spot speeds, speed limit compliance, motor-vehicle crashes, and resident opinions were considered. *Method:* Spot speeds were collected at 18 "between-hump" locations. Motor-vehicle crash data were obtained for "before" and "after" periods of equal duration. A total of 436 residents were surveyed; 184 responded. *Results:* The mean and 85th percentile speeds decreased at 14 and 15 locations, respectively. The average reduction in the 85th percentile speed (3.4 mph or 5.4 km/h) was significant in flat and rolling terrain, but not on uphill or downhill segments. The number of sites with 50% speed limit compliance increased from 4 to 12. The number of motor-vehicle crashes decreased from 10 to 9; the change was not significant, but injury crashes decreased from five to one. Regarding the residents, 30% were positive, 25% were negative, and 45% offered suggestions, some of which were conflicting. *Discussion:* Further study is needed on speed hump spacing and speed tables in hilly terrain. Example results should be shared with residents to inform their decision-making. *Summary:* At least 78% of the sites experienced a decrease in the mean or 85th percentile speed, or an increase in speed limit compliance. *Impact on Industry:* These findings should be useful to agencies that are planning or implementing traffic calming projects, and to analysts.

Keywords: Traffic calming; Traffic safety; Neighborhood traffic management; Speed limit compliance; Pedestrian safety

1. Introduction

Traffic calming has been defined as "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). The Salt Lake City Traffic Management Program (TMP), originally referred to as the "Traffic Calming Program," was initiated in 1997. The goals of the program are to improve the livability and quality of life in neighborhoods, and to promote walking and healthy lifestyles. A secondary goal is to ensure that collector and arterial streets are used for their intended purpose, and to deter traffic from diverting onto local streets. To reach these goals, the objectives of the program are to:

- Reduce speeding on residential streets;
- Influence non-local commuters to use commuter-oriented streets; and
- Improve the safety and traveling experience of pedestrians, bicyclists, and other road users by influencing driver behavior.

The TMP, in its most recent, expanded version (SLCCEDD, 2003), features a menu of traffic management tools and attributes, as shown in Table 1. Eligibility for traffic management on a street is determined using a formula that is a function of directional traffic volumes, 85th percentile speeds, pedestrian trip generators, sidewalk availability, designation

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of the street as a bus route, and designation of the street as a bicycle route. Attention is initially drawn to a street by local residents: an application must be completed, and at least 10 area residents must sign the form. As of August 2003, there were 32 completed, 13 active, and 110 eligible traffic management projects located throughout Salt Lake City.

2. Study objectives

The purpose of this study was to evaluate the effectiveness of speed humps and tables in meeting the first and third objectives of the Salt Lake City TMP. Also, although not explicit in the TMP objectives, another purpose was to understand the residents' perspectives in "calmed" neighborhoods. As indicated in Table 1, speed humps and tables are just two of 25 different calming tools considered in the TMP. Speed humps and tables continue to be the most prevalent calming devices used in Salt Lake City, though. As of 2002, Salt Lake City had installed 64 speed humps or tables, three median islands, one traffic circle, one curb extension, one entry-way, and several diverters. Some 32 streets featured one or more humps or tables.

Table 1
Salt Lake City Traffic management tools

Tool	Application	Construction or special installation
Adopt-a-Crosswalk	Local, collector, arterial streets Emergency routes	No
Beyond Traffic Calming (*neighborhood curb appeal enhancement*)	Local, collector, arterial streets Emergency routes	No
Bicycle Lanes	Local, collector, arterial streets Emergency routes	Yes
Chicanes	Local, collector streets Emergency routes	Yes
Chokers or Curb Extensions	Local, collector, arterial streets Emergency routes	Yes
Crosswalk Lighting (pavement and overhead)	Local, collector, arterial streets Emergency routes	Yes
Diverters	Local streets Emergency routes	Yes
Driver Feedback Radar Speed Limit Sign	Local, collector, arterial streets Emergency routes	Yes
Driver Safety Signs on Garbage Cans	Local, collector, arterial streets Emergency routes	No
Driver Safety Signs on Lawns	Local, collector, arterial streets Emergency routes	No
Enforcement	Local, collector, arterial streets Emergency routes	No
Entrance Ways (*special neighborhood entrance features*)	Local, collector, arterial streets Emergency routes	Yes
Medians	Local, collector, arterial streets Emergency routes	Yes
Neighborhood Pace Car	Local, collector, arterial streets Emergency routes	No
Neighborhood Speed Watch	Local, collector streets Emergency routes	No
Pavement Markings	Local, collector, arterial streets Emergency routes	Yes
Road Closure	Local streets	Yes
Speed Display Trailer	Local, collector, arterial streets Emergency routes	No
Speed Humps	Local, collector streets	Yes
Speed Limit Signs	Local, collector, arterial streets Emergency routes	No
Speed Table	Local, collector streets	Yes
Street Light Banners	Local, collector, arterial streets Emergency routes	No
Street Narrowing	Local, collector, arterial streets Emergency routes	Yes
Textured Crosswalks	Local, collector, arterial streets Emergency routes	Yes
Traffic Circles	Local, collector streets Emergency routes	Yes

3. Setting

Salt Lake City had a population of 181,743 in 2000, in an area of 109.1 sq mi (282.6 sq km). Salt Lake City is the center of the Wasatch Front urbanized region, which had a population of 1.6 million in 2000. Salt Lake City's population grew at an annual rate of 1.3% between 1990 and 2000, while the urban region grew by 2.4% annually. The growth in traffic volumes on Salt Lake City's streets is fueled by internal and regional population and economic growth, and has been stimulated by Salt Lake City's hosting of the 2002 Winter Olympic Games. Salt Lake City features seven, large residential communities, with each comprised of multiple, informally-designated neighborhoods. The seven communities and their year 2000 populations are (SLCEDRC, 2004): Avenues (16,799), Capitol Hill (8,193), Central City (49,635), East Bench (25,251), Northwest (30,622), Sugar House (28,485), and West Salt Lake (22,758). A total of 45 traffic management projects had been either implemented or were under development in all seven of the communities as of August 2003. Most of the TMP actions had been taken in the Avenues, Central City, East Bench, and Sugar House, primarily because of the involvement of local residents. A map of Salt Lake City, showing completed, pending, eligible, and ineligible TMP project locations, as well as emergency response routes, is provided in Fig. 1.

4. Descriptions

A speed hump is a raised, paved deflection, oriented transversely to the flow of traffic, and having a sinusoidal, circular, parabolic or flat-topped profile in the direction of travel. The purpose of the hump is to force drivers to reduce their speeds to mitigate an "unpleasant" bounce or jolt when traversing the device (Roess, Prassas, & McShane, 2004). The older speed "bump," in comparison, features a narrow, high profile that can damage a vehicle or lead to a loss of control if negotiated at an unsafe, high speed. The speed bump evolved into the speed hump because of the latter's flatter, "more forgiving" shape. The most popular type of speed hump is the Watts design, which features a parabolic profile, a maximum height of 3 to 4 in (7.5 to 10 cm), and a width of 12 ft (3.7 m) in the direction of travel. Salt Lake City was using a 14-ft (4.3 m) wide, 3.5-in (8.9-cm) high hump (see Fig. 2), as were other U.S. cities (Ewing, 1999).

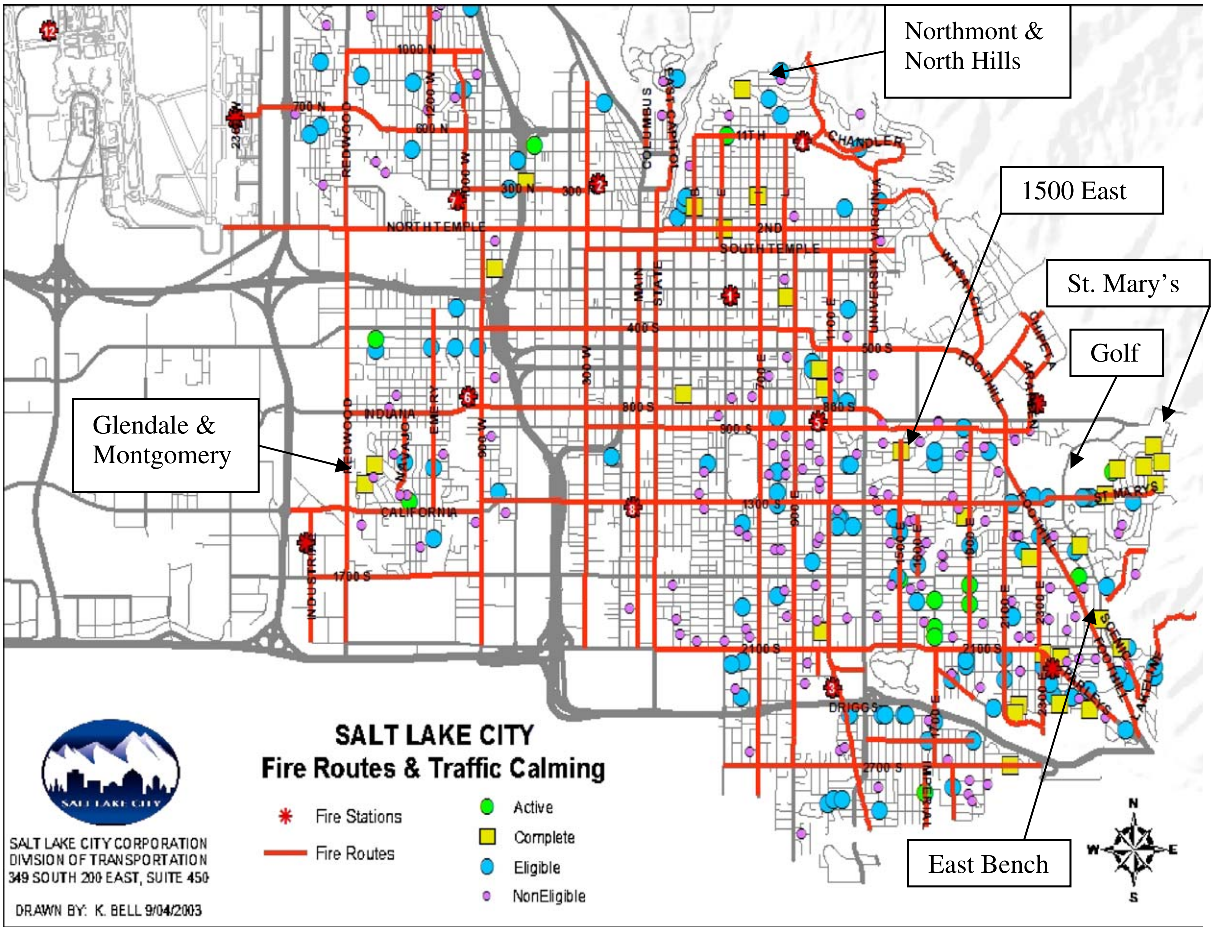

Fig. 1. Salt Lake City Traffic Calming Projects (SLCCEDD, 2003).

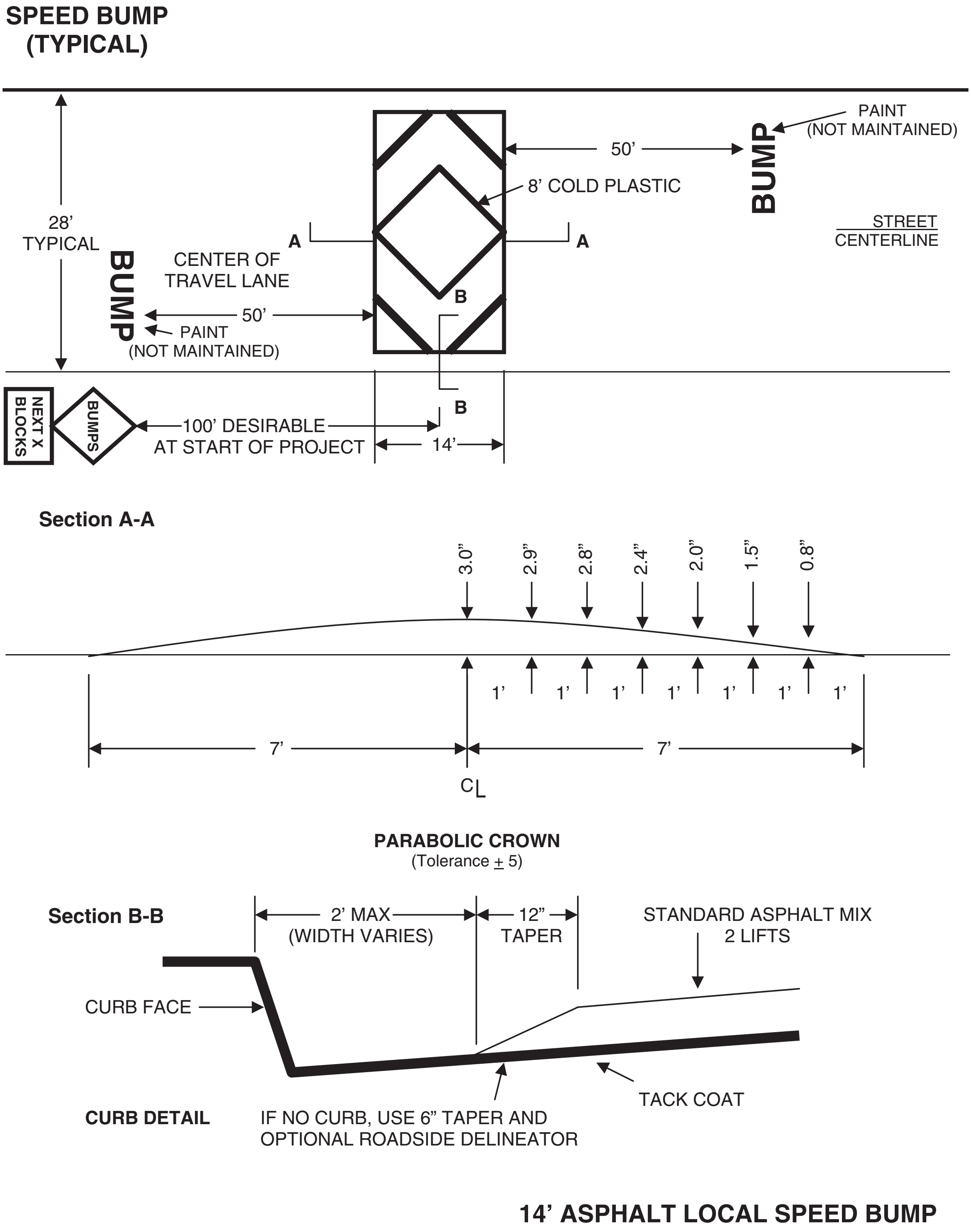

Fig. 2. 14-Foot (4.3-m) Speed Hump Design (Portland B. T. M., 1998).

The extra width is associated with a higher design speed (20 to 25 mph or 32 to 40 km/h) than the Watts hump (less than 19 mph or 30 km/h). The higher speed more closely matches typical residential street speed limits (Atkins, 1999). Further, the greater width reduces the impact on emergency vehicle response times (Roess et al., 2004). Several researchers have proposed speed hump geometric design standards, and have attempted to optimize hump size, shape, and height as a function of the response characteristics of motor vehicles (e.g., Fwa & Tan, 1992; Granlund, 2003; Maemori, 1995; Pedersen, 1998; Weber & Braaksma, 2000). The speed "table" is a variant of the speed hump. The table has the same height, but is wider, at 22 ft (6.7 m), than the hump, creating a flat section at the crest that can serve as an elevated pedestrian crossing. Salt Lake City was using speed tables as crossings. Speed humps and tables are usually accented by solid or striped painting; advance warning signs are commonly posted.

5. Literature review

5.1. History and development of traffic calming

Schlabbach (1997) stated that traffic calming had its genesis in The Netherlands, in the form of “woonerfs,” or residential precincts, designed to limit the mobility of motor vehicles in neighborhoods. A road hump with an elevation of 8 cm (3.1 in), installed at the end of an alley in Delft in 1970, was the first traffic calming fixture. By 1976, regulations that incorporated traffic calming features into design standards had been established. Other European nations followed suit, with Austria, Denmark, Germany, and Switzerland all adding traffic calming codes by 1984. Pharaoh and Russell (1991) observed that speed humps were rejected in Germany, but were employed extensively in Denmark and The Netherlands. In Denmark, speed humps were considered to be necessary for effective speed reduction. In The Netherlands, speed humps were being used to demarcate the boundaries of 30 km/h (19 mph) calmed streets; 50 km/h (31 mph) humps were being used on roads that provide access to residential streets (de Wit & Talens, 1998). Brindle (1997) reported that traffic calming *concepts* were borne in Great Britain during the 1960s; piecemeal and “patchy” applications followed there and in Australia during the 1960s and 1970s. Formal policies and standards were eventually developed, partially in response to the progress in continental Europe. There have been “a great deal of surveys and research works” on traffic calming in Europe (Schlabbach, 1997), but only a few of them isolate the effects of specific features such as speed humps. That is, most European studies have concentrated on the impacts of integrated traffic calming strategies. Atkins (1999) suggested that traffic calming *techniques* had been used in a few U.S. cities since the late 1940s. Several U.S. cities developed traffic calming programs during the 1980s to address citizen concerns; by 1996, over 100 cities and counties reported the use of at least one calming measure.

5.2. Performance of speed humps

To ascertain the effectiveness of speed humps, eight different “performance” measures can be used: speed hump influence area, at-hump speed, between-humps speed, the location of the maximum speed (relative to the locations of upstream and downstream humps), speed limit compliance, traffic volumes, motor-vehicle crashes, and community perspectives. The influence area includes the motor-vehicle deceleration-acceleration profile upstream and downstream of a speed hump. While the between-humps speed is measured at *any* point between successive humps, the maximum speed is measured where the effects of upstream and downstream humps are minimal.

Barbosa, Tight, and May (2000) modeled the speed profile of a motor vehicle as it negotiates a series of traffic calming devices, including speed humps and tables. The authors determined that the speed of a motor vehicle at any given point along a calmed road is a function of its entry speed (i.e., upstream of all calming devices), the upstream distance from the speed checkpoint to the device just passed, and the distance downstream to the next device. A speed hump (dimensions not provided) had an influence area of 230 ft (70 m) and space mean speed of 17.69 mph (28.47 km/h). For a speed table, the influence area was 205 ft (62.4 m) and the space mean speed was 15.93 mph (25.64 km/h). The maximum speed occurred at 55% to 64% of the separation distance between devices. In comparison, Mak (1986) observed an area of influence of about 100 ft (30.5 m) around each 8 to 10.5 cm (3.1 to 4.1 in) speed hump.

The effects of speed humps on motor-vehicle speeds have been investigated by a number of researchers. Their findings are summarized in Table 2. Based on data from 255 sites in the United States, the U.K. and Australia, 85th percentile speeds at speed humps ranged from 12.9 to 26.0 mph (20.8 to 41.8 km/h); 85th percentile speeds *between* speed humps ranged from 16.3 to 43.7 mph (26.2 to 70.3 km/h). The reduction in between-humps speeds ranged from 1.7% to 29.7%. The effects of speed humps were observed to vary as a function of speed limit and speed hump dimensions (height and width). The authors did not consistently report these parameters. Also, Ewing (2001) argued that the performance of a speed hump is partially dependent on where the measurement is taken relative to the location of the hump. He noted that many analysts did not report this information.

Several detailed findings from the studies cited in Table 2 are particularly notable. For example, Stephens (1986) determined that between-hump speeds increased with the hump separation distance, as follows:

$$H_s = 0.50^*\left[2.59^*(V_{85})^2 - 656\right], \tag{1}$$

where $\mathrm{H_s}$ = optimal spacing of road humps (ft), $\mathrm{V_{85}}$ = desired 85th percentile speed (mph) between road humps, with $\mathrm{V_{85}} > 22.5$ mph.

Stephens also observed a 4 mph (6.4 km/h) crossing speed difference between 4-in (10.2 cm) and 3-in (7.6 cm) speed hump heights, the lower height being associated with a greater speed. Mak (1986) revealed that large trucks had the lowest speed hump crossing speeds (12.2 mph or 19.6 km/h for a tractor-trailer); subcompact cars had the highest crossing speeds (16.3 mph or 26.2 km/h).

Evans (1994) assessed speed limit compliance in Oxfordshire County, England. With 85-mm (3.3-in) hump heights, speed limit compliance increased from 34%–80% “before” to 91%–99% “after;” with 75-mm (3.0-in) humps, compliance increased from 20%–66% before to 73%–98% after.

Table 2
At-Hump and between-humps speeds in U.S. and European cities

Location	Speed limit	Speed hump size	At-hump speed	Between-humps speed	Reference
				Speed reduction (%)	
Brea, California (7 sites)	NA	NA	*19.0 to 26.0*	*23.0 to 32.0 (22.4%)*	Chadda and Cross (1985) and Stephens (1986)
Corio, Australia (3 sites)	NA	NA	*13.0 to 16.2*	*25.5 to 28.0 (26.8%)*	
various U.K. (8 sites)	NA	NA	*12.9 to 16.3*	*16.3 to 27.2 (29.7%)*	
San Antonio, Texas (research institute property)	25	Height: 8–9 cm (3 sites)	15.3 to 20.4	–	Mak (1986)
		Height: 9–10 cm (3 sites)	14.6 to 17.1		
		Height: 10.5 cm (1site)	14.0		
Omaha, Nebraska (10 sites)	25	Height: 10 cm Width: 3.7 m	–	*31.5 to 36.5 (6.2%)*	Gorman et al. (1989)
Oxfordshire County, England	NA	Height: 7.5 cm (3 sites)	–	*25 to 34 (25.6%)*	Evans (1994)
		Height: 6.0 cm (1 site)	–	*25 (28.6%)*	
Manatee County, Florida	20 (8 sites)	NA	–	*19.3 to 29.9 (11.7%)*	Aburahmah and Assar (1998)
	25 (4 sites)	NA	–	*26.0 to 32.1 (23.9%)*	
	30 (5 sites)	NA	–	*34.2 to 43.7 (1.7%)*	
various U.S.	NA	Width: 3.7 m (184 sites)	*19*	27.3 (22.2%)	Ewing (2001)
		Width: 4.3 m (15 sites)	*22*	25.6 (23.1%)	

NOTES: Speeds are in mph. Divide mph by 0.6214 to obtain km/h. *Italics* indicate 85th percentile speeds. Speeds in regular font are means. A speed reduction is the multiple-site average percent change from before to after the installation of speed humps.

Aburahmah and Assar (1998) examined 18 calmed streets in Manatee County, Florida. At eight locations with a 20 mph (32 km/h) speed limit, 85th percentile speeds decreased from 29.7 to 44.8 mph (47.8 to 72.1 km/h) “before” to 19.3 to 29.9 mph (31.1 to 48.1 km/h) “after.” At four locations with a 25 mph (40 km/h) speed limit, 85th percentile speeds decreased from 26.6 to 36.7 mph (42.8 to 59.0 km/h) “before” to 26.0 to 32.1 mph (41.8 to 51.7 km/h) “after.” At five locations with a 30 mph (48 km/h) speed limit, 85th percentile speeds decreased from 36.2 to 50.0 mph (58.3 to 80.50 km/h) “before” to 34.2 to 43.7 mph (55.0 to 70.4 km/h) “after.” The authors did not report on the hump dimensions or spacings.

Findings regarding the impact of speed humps on traffic volumes have been inconclusive. Chadda and Cross (1985) and Stephens (1986), for example, found that traffic volumes along 14 streets in Australia, the U.K. and the United States decreased between 1% and 64% following the introduction of road humps. Evans (1994) found that the change in traffic volumes in Oxfordshire ranged from a 36% decrease to a 2% increase following the establishment of humps. Aburahmah and Assar (1998) observed traffic volume changes in Manatee County, Florida to range from a 30.0% decrease to a 200.5% increase. No explanation was offered for the extremely wide range. In Mira Mesa, a San Diego, California community, the decrease in 24-hour traffic volumes following the introduction of speed humps ranged from 0.1% to 57.8% (Ewing, 1999). Ewing (2001) reported an overall average decrease in traffic volumes of about 17%, based on data from 204 sites. In general, the magnitude of the change in traffic volumes is strongly affected by the role of the calmed street in local circulation. Before-after traffic volume analysis must be performed within the context of the street, the surrounding streets, and the neighborhood.

Only a few researchers have examined motor-vehicle crashes before and after the installation of speed humps. Gorman, Moussavi, and McCoy (1989) studied 19 street segments in Omaha, Nebraska. The number of crashes decreased from 40 before to 30 after speed humps were installed. Crashes that resulted in injuries increased, however, from two to five. The total number of crashes increased along 9 of the 19 streets. The authors found that none of the changes were significant at a 95% level of confidence. Evans (1994) reported a 59% decrease in motor-vehicle crashes following the establishment of humps. Fatal and serious-injury crashes decreased from 26% of all crashes before to 10% “after.” Ewing (2001) found that the average number of collisions at 54 sites decreased by an average of 14% following treatment with speed humps. A decrease of an average of 47% was observed at 51 sites that had been treated with speed tables. None of the authors reported the lengths of the “before” or “after” study periods.

5.3. Community perspectives

Gorman et al. (1989) found that 82% of 147 residents in Omaha, Nebraska were in favor of speed humps, stating that they were effective. The 18% of respondents who were against the humps commented that speeding still existed, street noise levels had increased, fewer on-street parking spaces were available, and some drivers were infringing on adjacent landscaping to avoid the humps. In Oxfordshire, England, 18 months following the introduction of speed humps, 59% of 826 residents were satisfied and 35% were dissatisfied (Evans, 1994). Bus companies were among the sternest critics of the humps, stating that their passengers were inconvenienced and experienced discomfort, and that their maintenance costs had increased. Dabkowski (1998) stated that a number of agencies in North America had removed speed humps because of public outcry, and that some had instituted legal arguments against their use. Davis and Lum (1998), in a study of San Leandro, California’s pilot traffic calming program, found that 43% of 60 residents who lived within 150 ft (46 m) of a speed hump said that street noise had increased. Speed humps were nonetheless popular among Salt Lake City's residents, with many requests for the devices in response to the program. Cline and Dabkowski (1999) reported that residents in Alhambra, California asked that speed humps be removed once drivers began to run their vehicles "down the gutters" to avoid the humps. In Beverly Hills, California, 3.5-in (8.9-cm) speed humps were "too noisy;' 3-in (7.6-cm) humps were preferred. In Sarasota, Florida, the Circuit Court declared that speed humps were not federally controlled or regulated, and thus were in violation of state law. Givens (2003) discussed a civil lawsuit in Berkeley, California, in which a resident contested the legality of traffic calming devices. The California Supreme Court ruled that speed humps were permitted, but their deployment was "at the sole risk of the (associated) agency." Wooley and Khasho (2004) reported that, following the completion of traffic calming projects in 17 Beaverton, Oregon neighborhoods, 54% of 264 residents thought that speeding had reduced, 67% observed no difference in traffic volumes, 46% felt that safety had been improved, and 38% agreed that their neighborhood had become "more livable."

6. Method

6.1. Study sites

Before-after motor-vehicle speed data were collected on 12 streets in six Salt Lake City neighborhoods. These streets were among the earliest "participants" in Salt Lake City's TMP. Although Vaterlaus and Timothy (2000) had conducted an earlier study of four TMP implementations in Salt Lake City, city engineers had a keen interest in the effects of traffic calming on the 12 streets. A survey of the residents who were living along the study streets was also conducted. Motor-vehicle crash data for the 12 streets, obtained from the Utah Department of Transportation's (DOT's) crash data delivery system (CDDS), were also gathered. The Salt Lake City DOT collected the speed data; one of this paper's coauthors conducted the survey in cooperation with the Salt Lake City DOT. An analysis of before-after traffic volumes was not performed because of the lack of before-after data on parallel and "side" streets.

The 12 streets studied are located in four of Salt Lake City's seven communities. Two of the streets are in the Upper Avenues neighborhood (Avenues community), one street is in the Harvard-Yale neighborhood (Central City community), seven streets are in the East Bench community, including four in the St. Mary's neighborhood, and two streets are in the Glendale neighborhood (West Salt Lake community). Eleven of the study streets are located in residential areas, while one of the streets traverses a golf course. With the exception of the latter, all of the streets serve residences, churches, and neighborhood retail, with driveways providing direct access. The streets are listed in Table 3. Wasatch Drive and 1500 East are neighborhood collectors; the others are local streets. All of the streets have two lanes and a speed limit of 25 mph (40 km/h). On-street parking is allowed on all of the streets except Wasatch Drive adjacent the golf course. The Utah Transit

Table 3
Speed hump locations and street characteristics

Street	Neighborhood	Terrain	Length	Endpoints	Calming devices
Glendale Dr	Glendale	Flat	2,716 ft 828 m	Traffic signal Hairpin curve	5 speed humps 1 speed table
Montgomery St	Glendale	Flat	2,002 ft 610 m	Hairpin curve Stop sign	5 speed humps
1500 East	Harvard-Yale	Rolling	2,532 ft 772 m	Stop sign 4-way stop sign	4 speed humps 3 speed tables 1 4-way stop sign
Kennedy Dr	St. Mary's	Downhill westbound	4,026 ft 1,227 m	Cul-de-sac 4-way stop sign	2 speed tables
Oakhills Dr	St. Mary's	Rolling	2,350 ft 716 m	Stop sign Stop sign	4 speed humps
Vista View Dr	St. Mary's	Downhill southbound	964 ft 294 m	4-way stop sign Direction change	2 speed humps
St. Mary's Wy	St. Mary's	Downhill westbound	3,988 ft 1,216 m	Direction change Stop sign	5 speed humps 1 stop sign
Northmont Dr	Upper Avenues	Downhill westbound	3,201 ft 976 m	Drainage dip Hairpin curve	2 speed humps
North Hills Dr	Upper Avenues	Downhill eastbound	2,171 ft 662 m	Hairpin curve Direction change	2 speed humps
Skyline Dr	East Bench	Downhill westbound	3,978 ft 1,213 m	Stop sign T-intersection	2 speed humps
Wasatch Dr	East Bench	Rolling	11,625 ft 3,543 m	Stop sign Stop sign	17 speed humps 1 speed table 2 2-way stop signs 3 4-way stop signs

Authority was providing fixed route bus service on Glendale Drive, Montgomery Street, and 1500 East as of the time of the study. Kennedy Drive and Wasatch Drive are bike routes, while 1500 East has bike lanes. Glendale Drive and Montgomery Street are flat and level; 1500 East and Wasatch Drive traverse rolling terrain; the other streets are in hilly areas. A total of 48 speed humps and seven speed tables along the 12 streets were considered in the evaluation. Speed humps and tables in the St. Mary's area were being tested at the time of the study. As of 2002, 21 rubber speed humps and tables had been temporarily installed in the area. The spacing between humps, tables and contributing, adjacent traffic controls on all 12 streets ranged from 181 ft (55 m) to 1,221 ft (372 m). In one case, a traffic control device was located within 99 ft (30 m) of a speed hump. The average spacing between humps, tables, and traffic controls, including dead ends and hairpin curves, was as follows:

- Bonneville Golf Course (Wasatch Dr): 842 ft (257 m)
- East Bench (Skyline Dr; Wasatch Dr): 528 ft (161 m)
- Glendale neighborhood (Glendale Dr-Montgomery St): 363 ft (111 m)
- Harvard-Yale neighborhood (1500 East): 281 ft (86 m)
- St. Mary's neighborhood (five streets): 687 ft (209 m)
- Upper Avenues neighborhood (Northmont Dr-North Hills Dr): 1,074 ft (327 m).

7. Speed data collection

Spot speed data were collected by the Salt Lake City DOT at a number of checkpoints along the 12 roads before and after the installation of speed humps. At each spot, speed data, along with traffic volumes, were collected over a 24-hour period during a weekday during favorable weather conditions. "Before" data were generally collected between 1998 and 2002, while "after" data were collected from one month to two years after installation. Pneumatic tubes were placed across each road to collect the speed data. There was no human observer or video camera at any of the sites, so it was not possible to discern vehicle types, vehicle turning or parking activity, platoons, or interference from crossing pedestrians, bicycles, or stopping buses. The tubes collected time mean but not space mean speeds, so it was not possible to generate speed profiles. The location of each speed data collection point was recorded, so the distance of each point from upstream and downstream speed humps or traffic controls was determined. Of the 48 data collection points, 30 were located within either the deceleration or acceleration zone of motor vehicles, as estimated from the findings of Barbosa et al. (2000). These sites were excluded from the analysis, as they did not capture the maximum speed of travel between calming devices. By recording a speed that was influenced by a nearby speed hump, table, or control, the calming devices would have seemed more effective than they actually were. The speed data were grouped into 5 mph bins by Salt Lake City analysts. The speeds of individual motor vehicles were not available to the research team. Characteristics of the 18 sites are summarized in Table 4.

8. Speed data transformation

The 18 sites selected for further analysis are located along nine streets in six neighborhoods. The speed data were tabulated according to the number of vehicles traveling

Table 4
Spot speed locations, calming devices and sources of traffic friction

Neighborhood	Street	Traffic friction	Route	Distance to devices		Adjacent calming devices	
				Upstream	Downstream	Upstream	Downstream
Bonneville Golf	Wasatch Dr	Bike route	North	300 ft	180 ft	Speed hump	Speed hump
		Golf xing		309 ft	2,332 ft	Speed hump	Stop sign
			South	2,332 ft	309 ft	Stop sign	Speed hump
East Bench	Skyline Dr	Parking	East	381 ft	228 ft	Stop sign	Speed hump
				893 ft	1,867 ft	Speed hump	T-intersect
			West	1,867 ft	893 ft	T-intersect	Speed hump
				228 ft	381 ft	Speed hump	Stop sign
	Wasatch Dr	Bike route	North	159 ft	87 ft	Speed hump	Speed hump
		Parking	South	239 ft	216 ft	Speed hump	Speed hump
Glendale	Glendale Dr	Bus route	North	271 ft	187 ft	Speed hump	Speed hump
		Parking					
	Montgomery St	Bus route	South	258 ft	140 ft	Speed hump	Speed hump
		Parking					
Harvard-Yale	1500 East	Bike lane	North	159 ft	100 ft	Speed table	Speed hump
		Bus route Parking	South	103 ft	78 ft	Speed hump	Speed hump
St. Mary's	Kennedy Dr	Bike route	East	359 ft	301 ft	Speed table	Speed table
		Parking	West	301 ft	359 ft	Speed table	Speed table
	Vista View Dr	Parking	North	350 ft	218 ft	Speed hump	Speed hump
Upper Avenues	Northmont Dr	Parking	East	412 ft	809 ft	Speed hump	Speed hump
			West	809 ft	412 ft	Speed hump	Speed hump

NOTE: All of the streets experienced additional "friction" from driveways. Divide ft by 3.2808 to obtain m.

at the midpoint of each 5 mph bin. To facilitate the statistical analysis of the data, it was useful to transform the discrete speed distributions into continuous models. The transformation was based on the "before" speed distributions from all 48 sites (two directions of travel per site, so 96 distributions). The 24-hour directional traffic volumes at these sites ranged from 206 to 2,610. Since the volumes were low, it was assumed that the motor-vehicle speeds on the streets were independent and not influenced by car-following. Hazelton (2004) noted that it is common to assume a Gaussian (normal) time mean speed distribution and independent vehicles in spot speed studies. To verify the Gaussian assumption, the Jarque-Bera test of normality (Bera & Jarque, 1981) was applied to the 96 spot speed distributions. This test uses the skewness and kurtosis of a set of values to compute a test-statistic that is chi-square distributed with two degrees of freedom. The normality assumption was violated in 90 of the 96 cases. The distribution of speeds from one of the sites at which the normality assumption was *not* violated is shown in Fig. 3 (both the before and after speeds are shown). After careful evaluation, the research team decided that the violation of normality was attributable to the binning of the data, and that the continuous speed distributions may indeed be Gaussian. The normal distribution model was, therefore, applied. The first application of the normal model was to compute the 85th percentile speed at each of the 18 sites, as follows:

$$X_{85} = \sigma Z_{0.85} + \mu, \tag{2}$$

where X_{85} = 85th percentile speed, σ = standard deviation of the speeds at a given site, $Z_{0.85}$ = standard normal variate corresponding to a standard normal density of 85% = 1.0365, and μ = mean of the speeds at a given site.

To investigate the possibility of combining the data from two or more of the 18 sites, analyses of variance (ANOVAs) were performed. In each ANOVA, the null hypothesis was that the mean speed from two or more sites was the same. That is, the analysis sought to determine if the distributions of "before" speeds at two or more sites were similar. The null hypothesis was rejected in all cases, in part because the sample of vehicles was fairly large at each site. The conclusion was that the distribution of motor-vehicle speeds at each of the 18 sites was unique.

9. Survey design

A total of 436 surveys were distributed in December 2002 by regular mail to residents of the streets that had been "calmed;" 184 forms were returned, for a return rate of 42.2%. The "maturity" of the speed humps or tables ranged from just a few months to over two years. The number of surveys distributed to each neighborhood was known, but the neighborhood *from* which a survey was returned was not recorded. It was not possible, therefore, to discern any differences in the responses according to the age of the calming devices or the neighborhood. A total of 112 of the respondents provided comments.

10. Results

10.1. Mean and 85th percentile speeds

Pairwise comparisons of the "before" and "after" mean speeds were performed at each of the 18 sites. The conclusion was that the before-after change in speeds was significant at a 95% level of confidence in each case. The change in the mean speed at each location ranged from −6.8 mph (−10.9 km/h → reduction) to 1.8 mph (2.9 km/h). The mean speed was reduced at 14 locations, and was increased at four. The change in the 85th percentile speed at each location ranged from −8.6 mph (−13.8 km/h) to 2.1 mph (3.4 km/h). The 85th percentile speed was reduced at 15 locations, and was increased at three. The "before" 85th percentile speeds ranged from 27.1 to 37.9 mph (43.6 to 61.0 km/h); the "after" 85th percentile speeds ranged from 27.2 to 38.7 mph (43.8 to 62.3 km/h). Interestingly, the

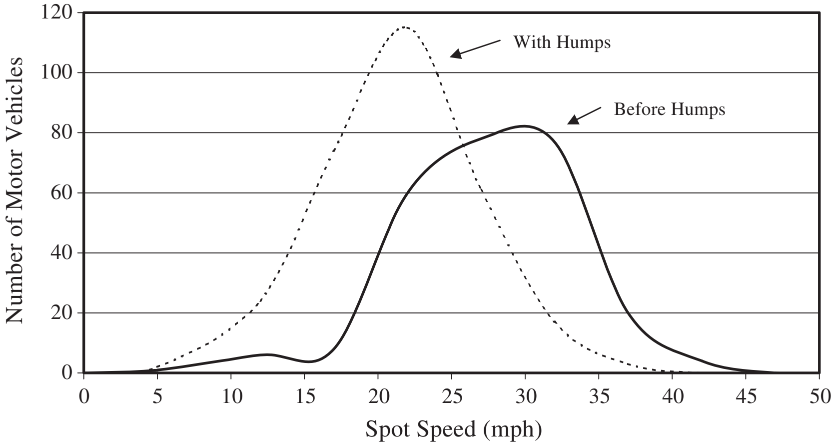

Fig. 3. Distribution of Spot Speeds on Northmont Drive, Salt Lake City.

range of 85th percentile speeds shifted to the right (i.e., the speeds increased) and widened following the introduction of speed humps and tables. These results are summarized in Table 5.

The average change in the 85th percentile speed at all 18 sites was −3.4 mph (−5.4 km/h). The reduction was significant in that the 95% confidence interval did not include zero, suggesting that the program was effective on a broad scale. To assess the effects of terrain on the changes in speeds, the sites were classified according to flat (2 locations), rolling (7), uphill (5), and downhill (4) topography. The average reduction in the 85th percentile speeds at the two sites in flat terrain was 5.0 mph (8.1 km/h), while the average for the seven sites in rolling terrain was 4.8 mph (7.7 km/h). The speed reductions for the two site types were significant at a 95% level of confidence. Although the average reductions for uphill and downhill sites were positive (2.5 mph or 3.9 km/h and 1.2 mph or 2.0 km/h, respectively), the changes were not significant. The suggestion is that motor-vehicle speeds on steep hills are not fully controlled by speed humps and tables. As shown in Table 6, the coefficient of variation was high in all cases. This was partially because of the small number of sites, but was primarily because of the wide variation in speeds prior to hump installation, as well as the variation in driver responses. Not enough data were available to evaluate speed humps and tables separately: only 3 of the 18 sites featured speed tables.

11. Speed limit compliance

The probability that an "after" speed was equal to or less than 25 mph (40 km/h) at each of the 18 sites was computed. This analysis was used to determine the effectiveness of the speed humps and tables in increasing the level of speed limit compliance. To allow for rounding, a speed of 25.499 mph (41.0 km/h) was used as the upper limit in the analysis. The probability computations were based on the value of the standard normal density function Φ(Z), where:

$$Z = (25.499 - \mu)/\sigma, \text{ with} \tag{3}$$

Z as the standard normal variate, and μ and σ as defined previously. Compliance with the 25 mph speed limit ranged from 12.0% to 74.7% of all motorists prior to the introduction of speed humps and tables. Following the installment of the calming devices, compliance ranged from 17.0% to 76.5%. Speed limit compliance increased at 14 of the 18 sites. The number of sites with at least 50% of all drivers complying increased from 4 to 12. The level of compliance *decreased* for the two directions of travel on Kennedy Drive in the St. Mary's area. Here, spot speeds were measured between two speed tables in hilly terrain. The indication is that the speed tables were not effective in this application. In general, though, the speed humps improved speed limit compliance. The results are summarized in Table 5.

12. Motor vehicle crashes

The numbers of motor-vehicle crashes occurring on the 12 study streets were tabulated before and after the installation of speed humps and tables. Motor-vehicle crash data were obtained from UDOT's CDDS. Crashes that occurred through December 2002 had been entered into the CDDS. Before and after periods of equal durations were established. "After" periods were set according to the

Table 5
Before-after speeds along calmed streets

Neighborhood	Street	Route	Sample size		Mean speed		85th % speed		% <25 mph	
			Before	After	Before	After	Before	After	Before	After
Bonneville Golf	Wasatch Dr	North	1,319	1,510	32.0	25.2	37.9	30.2	12.7	52.4
			1,185	1,238	32.0	29.4	37.7	35.4	12.0	25.3
		South	1,576	1,423	31.4	30.5	36.9	36.8	13.7	21.0
East Bench	Skyline Dr	East	589	489	29.0	23.2	35.6	29.0	28.8	66.0
			881	807	22.7	23.4	27.1	28.2	74.7	67.7
		West	828	820	27.0	27.6	32.3	32.2	38.3	32.1
			356	335	28.3	23.2	35.6	29.4	34.5	65.0
	Wasatch Dr	North	1,039	1,191	29.7	23.5	35.4	28.2	22.6	67.1
		South	1,019	941	28.7	23.4	34.1	28.9	26.6	65.2
Glendale	Glendale Dr	North	590	441	26.6	22.9	35.0	27.8	44.5	71.0
	Montgomery St	South	484	109	25.1	23.0	32.1	29.3	52.1	65.8
Harvard-Yale	1500 East	North	2,363	2,097	30.6	22.9	36.3	27.7	17.8	71.2
		South	1,997	1,179	25.2	22.9	29.3	27.0	52.9	74.5
St. Mary's	Kennedy Dr	East	1,014	981	28.3	29.6	34.5	35.7	32.2	24.0
		West	1,213	1,141	30.0	31.8	36.6	38.7	23.9	17.0
	Vista View Dr	North	607	512	24.1	22.8	28.8	27.3	61.9	73.2
Upper Avenues	Northmont Dr	East	254	296	27.6	21.6	33.7	27.2	36.2	76.5
		West	206	218	28.4	26.5	35.3	34.5	33.0	45.2

NOTE: Speeds are in mph. Divide mph by 0.6214 to obtain km/h.

Table 6
Reductions in 85th percentile speeds along calmed streets

Locations	Average	Standard deviation	COV	Does 95% confidence interval include zero?
All 18 sites	3.36 mph (5.41 km/h)	3.53 mph (5.68 km/h)	1.05	No
2 sites in flat terrain	5.03 mph (8.10 km/h)	3.10 mph (4.99 km/h)	0.62	No
7 sites in rolling terrain	4.76 mph (7.66 km/h)	3.24 mph (5.21 km/h)	0.68	No
5 sites on ascents	2.45 mph (3.94 km/h)	3.89 mph (6.26 km/h)	1.59	Yes
4 sites on descents	1.21 mph (1.95 km/h)	3.50 mph (5.63 km/h)	2.89	Yes

length of time from speed hump and table installation until December 2002. “Before” periods were then determined by “counting back” from the installation time. The data are summarized in Table 7. Study periods ranged from 8 to 94 months. Because all of the study roads were either local streets or neighborhood collectors, with two-way daily traffic volumes between 500 and 5,500, there were a small number of crashes during the study periods. A total of 10 crashes occurred on the study streets during the before periods, while 9 occurred during the “after” periods. Because of the small numbers of crashes, it was not possible to discern any patterns or trends. For example, three of the collisions occurred during snowy or icy conditions, but 11 occurred when the weather was clear and dry. Five crashes occurred at night under street lighting, while 13 occurred during the daytime. There were two motor vehicle-pedestrian crashes, two motor vehicle-bicycle crashes, and four crashes involving two motor vehicles. The normal approximation test was used to determine if the change in the number of crashes was significant:

$$Z_t = \frac{(f_A - f_B)}{(f_A + f_B)^{0.5}} \tag{4}$$

where Z_t is the test statistic based on a standardized normal distribution of crashes, f_A is the “after” number of crashes, and f_B is the “before” number. In this application, $Z_t = -0.2294$, indicating that there was only a 59% level of confidence that the change in the number of crashes was significant. It would be interesting to continue monitoring these sites.

The distribution of outcomes during the before periods included five no-injury, two bruises-abrasions, one broken bones-bleeding wounds, and two fatal crashes. Both fatal crashes involved pedestrians. During the “after” periods, there were three no-injury, five possible-injury, and one broken bones-bleeding wounds crashes — the latter involved a bicycle. Injury crashes, therefore, were reduced from five to one following the introduction of speed humps. Using these numbers, $Z_t = -1.6330$, corresponding to a 94.9% level of confidence that the change in the number of injury crashes was significant. Drawing a conclusion based on just six crashes would not be good practice, however. As more recent crash data become available, the “before” period can be extended, thereby increasing the richness of information available for the analysis.

13. Discussion

13.1. Speed hump spacing

The average speed hump spacing at the 18 study sites ranged from 281 ft to 1,074 ft (86 m to 327 m). In comparison, Ewing (1999) reported a wide range of speed hump spacings in various urban applications (218 ft to 960 ft; 65 m to 290 m). Boulder, Colorado had

Table 7
Motor vehicle crashes on calmed streets

Street	Installation date	Study period	Study period length (months)	Crashes	
				Before	After
Glendale Dr	March 2000	5/97–12/02	68	1	5
Kennedy Dr	July 2001	1/00–12/02	36	2	0
Montgomery St	September 2000	5/98–12/02	56	1	0
North Hills Dr	February 1999	3/95–12/02	94	0	0
Northmont Dr	February 1999	3/95–12/02	94	1	0
Oakhills Dr	August 2002	3/02–12/02	10	0	0
St. Mary’s Dr	March 2002	5/01–12/02	20	0	0
Skyline Dr	February 2001	3/99–12/02	46	0	0
Vista View Dr	September 2002	5/02–12/02	8	0	0
Wasatch Dr (golf)	August 1999	3/96–12/02	82	0	0
Wasatch Dr (East Bench)	November 1999	9/96–12/02	76	2	0
1500 East	May 2000	9/97–12/02	64	3	4
Total				10	9

established a speed hump spacing guideline of 150 to 800 ft (46 to 244 m). While Salt Lake City did not have a speed hump spacing policy, TMP documentation suggested a range of 300 to 500 ft (91 to 152 m).

As shown in Eq. (1), there is a relationship between speed hump spacing and motor-vehicle speeds. Other speed hump spacing guidance has been developed (e.g., City of Belmont, 1999). Eq. (1) was applied to the 18 study sites, producing a broader range of speeds than was actually experienced. As an alternative, a relationship between spacing and 85th percentile speeds was investigated for the 18 study sites. The relationship was not strong, as suggested by Fig. 4, partially because there were so few data points. By observation, a correlation with 85th percentile speed appears to exist for short hump separation distances. The relationship is lost, however, as the spacing increases. Two of the points — those from the speed tables along Kennedy Drive in the St. Mary's area — are outliers. Removing these two sites, along with sites at which the hump spacing was greater than 1,000 ft (328 m), leaves 10 data pairs. An examination of the relationship between spacing and speed at these 10 sites revealed a slope coefficient of nearly zero, suggesting a weak linear codependence. Further investigation is warranted.

13.2. Resident opinions

Of the 112 survey forms on which the residents provided comments, a total of 33 (29.5%) were positive, 28 (25%) were negative, and 51 (45.5%) were neither positive nor negative, but were suggestions. Common positive comments included "keep the hump," "great idea," and "traffic volumes and speeds have been reduced." Repeated negative comments included "noise pollution and 'edge' driving have increased," "no value whatsoever," and "get rid of the humps." "Edge" driving referred to motorists who attempted to circumvent the speed humps and tables by letting their outside wheels roll along gutters. Possible suggestions for improvement included:

- The speed humps are too low.
- The speed humps are too high.
- Install speed humps in alternative or additional locations.
- Install other or additional calming measures, such as dips.
- Remove advance warning signage.
- Improve markings and signing.

The research team members do not know if Salt Lake City has attempted to implement any of the residents' suggestions. Some of the suggestions are clearly in conflict. It may be useful to share information with the residents on the effects of speed hump height, spacing, markings, signing, and other forms of traffic calming on motor-vehicle speeds. The information might boost the knowledge of residents on traffic calming options, thereby enabling them to play a greater role in the selection of calming approaches.

Vaterlaus and Timothy (2000) discussed resident involvement in the first four traffic calming feasibility studies conducted in Salt Lake City. One study was of Scenic Drive, which is located immediately to the south of Wasatch Drive in the East Bench. A survey of 24 residents found that 74% of them were interested in having speed humps installed.

Once a set of temporary humps were in place, only 56% were supportive of keeping them, despite a drop in 85th percentile speeds of between 1 and 6 mph (1.6 to 10 km/h). The humps were removed as a result of the drop in interest. A second study was of Northmont and North Hills Drives in the Upper Avenues neighborhood. Here, 97% of 32 survey respondents were supportive of installing speed humps (29 residents did not return surveys). After a set of temporary humps had been in place for a few months, a follow-up survey produced an increase in participation (48 respondents) and support (40 respondents). The speed humps on these streets are now permanent, and their speed data are

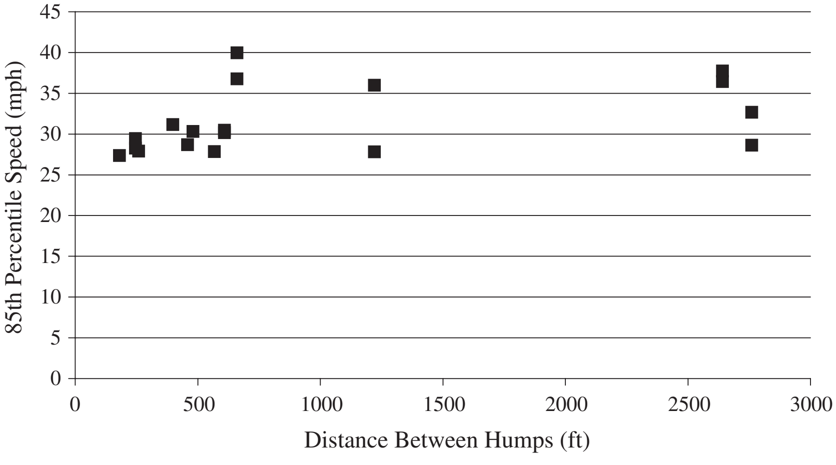

Fig. 4. Speed Hump Spacing vs. 85th Percentile Spot Speed.

included in this paper. A similar evolution occurred in Salt Lake City's Country Club neighborhood. A separate set of surveys was sent to the residents of each of three neighborhood streets. Survey response rates ranged from 65% to 100%; interest in speed hump testing ranged from 92% to 100%, and support for permanent installation ranged from 67% to 90%. Textured crosswalks and neighborhood entrance islands resembling gateways were tested along with the speed humps; only two entrance islands were retained in addition to the humps. As implied, the residents of the Country Club area remained heavily involved throughout the implementation of Salt Lake City's TMP. Speed data from this neighborhood were not available for this study.

13.3. Speed profiles and compliance

Not enough information was available for this study to ascertain the effects of traffic friction, such as bike lanes, bus stops, and driveways. Space mean speeds, rather than time mean speeds, would be useful for an analysis of these factors. Smith, Knapp, and Hallmark (2002), for example, obtained speed profiles along calmed streets in Atlantic, Iowa using a laser gun. The authors observed deceleration and acceleration zones in the vicinity of speed humps, with the zone lengths varying according to the local conditions, driver behavior, and vehicle type. Further research into the effects of local conditions on acceleration and deceleration rates would be useful.

The increase in speed limit compliance following the introduction of speed humps was, arguably, the best measure of success. Tignor and Warren (1991), in a study of 52 streets in urban, small urban, and rural areas, found that speed limit compliance ranged from 3% to 99%. The level of compliance was greatest on roads with prima facie limits, and where an engineering study had been done. The authors recommended that 70% to 90% of all motorists be in compliance with the speed limit, such that a 5-mph buffer between the prevailing and the maximum safe speed is maintained. Five of the 18 study sites featured a 70% or greater level of speed limit compliance following the installation of speed humps and tables, suggesting that further measures would be needed to reduce travel speeds. These might include closer speed hump separations, additional traffic calming devices, or, as suggested by several of the survey respondents, greater police enforcement.

13.4. Other observations

Bus service along Wasatch Drive was rerouted to a parallel street once the speed humps were introduced. A study of the impacts of the speed humps on bus operations, schedule adherence, patronage, passenger comfort, bus suspension systems, and other aspects of service was beyond the scope of this paper, but would be interesting research. A July 2004 field check revealed that 8 of the 21 temporary speed humps and tables in the St. Mary's area had been removed; the removed devices were not considered in the study. It was beyond the scope of the study to investigate the decision-making process regarding the removals, but standard procedure was for Salt Lake City to look for an approval rating of at least two-thirds of a street's residents to justify retention.

14. Summary

The impacts of speed humps and tables on 12 streets in Salt Lake City, Utah were investigated. Speed humps 14 ft (4.3 m) wide by 3.5 in (8.9 cm) high had been installed. Spot speeds were obtained between 1999 and 2002 at 18 "between-hump" locations along nine streets in six neighborhoods. Each site featured a unique (i.e., no two means were equal, with 95% confidence) and, approximately, Gaussian (normal) speed distribution. The mean speed decreased at 14 of the 18 locations following the introduction of speed humps. The 85th percentile speed decreased at 15 of the locations, changing between −8.6 mph (−13.8 km/h → reduction) to 2.1 mph (3.4 km/h). The range of 85th percentile speeds shifted to the right, from 27.1–37.9 mph (43.6–61.0 km/h) to 27.2–38.7 mph (43.8–62.3 km/h). The 18-site average change in the 85th percentile speed was a 3.4 mph (5.4 km/h) reduction. The change was not significant, however, at five uphill and four downhill sites. Two speed tables (22 ft or 6.7 m wide; same height as the speed humps) were located on hilly streets; the ineffectiveness of the tables in reducing spot speeds was probably more related to the terrain than to their geometry or size.

Compliance with each street's 25 mph (40 km/h) speed limit increased from 12.0%–74.7% before to 17.0%–76.5% after the introduction of speed humps. Speed limit compliance increased at 14 sites, while the number of sites at which at least 50% of the drivers were compliant increased from 4 to 12. The number of motor-vehicle crashes occurring along the 12 streets decreased from 10 during a "before" study period to 9 during an "after" study period of equal duration. The level of confidence in the significance of the decrease was 59%. The low level of confidence indicates that the speed humps and tables were potentially ineffective in meeting the third objective of Salt Lake City's TMP. The number of *injury* crashes decreased from five to one. The reduction was significant at a 94.9% level of confidence, although it is difficult to make recommendations based on the small number of crashes. The improvement of "user safety and traveling experience" might be evaluated by performance measures other than crashes; these, such as the number of pedestrian crossing opportunities, could give the speed humps and tables a more favorable safety review.

Overall, the speed humps and tables had the desirable effect of generally decreasing mean and 85th percentile speeds. The impacts were not consistent, but at least 78% of the sites experienced a decrease in the mean speed, a decrease in the 85th percentile speed, or an increase in speed limit compliance. There were not enough data to identify a relationship between speed hump spacing and 85th percentile speeds. Application of the Stephens relationship (Eq. (1)) yielded values that were different from those observed. The scatterplot in Fig. 4 suggests that between-hump speeds decrease as hump spacing decreases, but the relationship could not be quantified. Further research is needed on this relationship, as well as on continuous models for vehicle speed distributions, traffic diversion in response to speed humps and tables, and the combined effects of humps, tables, and other calming devices. It would also be useful to study the effects of speed humps and tables as they age, to determine if there is a diminishing impact over time. A deeper examination of the impacts of speed humps and tables would consider speed profiles between, upstream and downstream of devices, possibly to ascertain the effects of traffic flow "friction" (driveways, bus stops, bike lanes). The environmental effects of the devices, including the impacts on traffic noise and emissions, might also be examined (e.g., Houwing, 2003).

Given that the Salt Lake City TMP requires signatures from 10 residents to initiate a traffic calming action, it is possible that the involvement in this paper's survey (184 respondents) exceeded that of the neighborhood proposals. It might be useful for Salt Lake City to look into ways of increasing resident participation in traffic calming proposals; one approach would be to require a number of signatures that is in proportion to the number of affected households. About 55% of the study street residents who offered comments in a survey were either positive or negative about the devices. The other residents expressed conflicting suggestions for how traffic could be "better calmed." It may be useful to provide residents with example or expected program results, to facilitate informed decision-making.

15. Impact on industry

Traffic calming has been referred to as "complex and confusing. . .used by different people with different agendas" (Crouse, 2004). The reference was to traffic calming as a "prevention" rather than a "cure," in that driver behavior and skills are not directly addressed (Ahmad & Rahman, 2003). Huang and Cynecki (2000), for example, noted that there is no guarantee that motorists will slow down or yield when negotiating or traveling between traffic calming devices. One key finding in this study is that speed humps decreased 85th percentile between-hump speeds in flat and rolling terrain. A second finding is that speed tables — and maybe speed humps — were not effective in decreasing 85th percentile speeds or increasing speed limit compliance in hilly terrain. A third finding is that speed humps, in flat and rolling terrain, increased speed limit compliance; only 12 of 18 sites experienced an increase to 50% compliance, however. A fourth finding is that the speed humps and tables were not effective in reducing the number of crashes occurring along the associated streets, although they may have been effective in reducing the number of injury crashes. The first finding supports that of other studies that have produced similar results. The second finding suggests that forms of calming different from speed tables are needed in hilly terrain. The third finding indicates that speed humps increase speed limit compliance, but not to desirable levels. Supplementary forms of calming may be needed to boost the impacts of the speed humps. Regular or periodic enforcement may be needed to heighten the awareness of speed limits and the purpose of calming devices. The fourth finding implies that speed humps and tables do not reduce motor-vehicle crash occurrences, although they may reduce crash severity and have other safety-related benefits. These findings should be useful to agencies that are planning or implementing traffic calming projects, and to analysts who are involved in evaluation. Agencies must be able to justify the costs of speed humps and tables, which ranged between $4,000 and $12,000 each as of the writing of this paper (SLCCEDD, 2003).

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