Offset Speed Tables for Reduced Emergency Response Delay

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ABSTRACT

With the advent of speed humps (a.k.a. modern speed bumps) to reduce vehicle speeding on residential streets has come the unwanted cost of delay for Emergency Service Providers. Fire equipment, due to its size and weight, is particularly affected by speed humps. Past studies in Portland found delays per hump of up to 9.4 seconds for the 14-foot designs and 9.2 seconds for 22-foot speed tables. Testing of the offset speed table with median islands made advances in reducing delay for emergency vehicles into the 2-second range but was limited to use on wider streets due to the turning needs of larger fire equipment. This report provides a summary of the testing of the offset speed table with median islands as well as a recent alternative and makes a comparison to speed cushions, a tool often used where emergency response delay is of concern. This investigation was undertaken to evaluate a design that would permit the use of the offset speed hump on designated Emergency Response Routes regardless of the street width.

PORTLAND AND SPEED HUMPS

A Brief History

In 1991 the City of Portland's Office of Transportation (PDOT) undertook a study of speed humps in response to public demand for relief from the excessive and continual increase of traffic speeds. As the result of two years of testing, speed humps and speed tables became standard tools for addressing the problem of speeding on Portland's residential streets. In Phase III of the original 1992 speed hump tests, the Fire Bureau indicated a maximum comfortable speed of 20 mph for the 14-foot speed hump and 25 mph for the 22-foot speed table.[1]

The 14-foot speed hump was adopted for Local Service[2] streets that serve as neither a transit street nor a primary fire response route. The 22-foot speed hump, or table, was designed for Neighborhood Collector[3] streets that serve higher volumes of traffic, to minimize diversion potential, and on streets that are designated transit or primary fire response routes. Speed tables have reduced effect on transit buses and are easier for fire and emergency vehicles to negotiate than the 14-foot speed hump. The 22-foot speed table has proved effective in slowing average 85th percentile speeds along a street to 30 mph. Seventy percent of residents on traffic calmed streets have perceived a change in speed and over 60% perceived a change in traffic volume.[4] The Traffic Calming Program has been installing speed humps since 1992, and to date has installed over 650 speed humps and 180 speed tables. Demand for traffic calming in Portland continues with the current street project backlog exceeding 300 projects. It can be stated with certainty that speed humps will for the foreseeable future be a common tool to slow speeding traffic in Portland.

EMERGENCY RESPONSE ISSUES

Benefits have Costs

With the continued success of speed humps the demand for their use increased greatly. And though the Portland Fire Bureau recognized the community's need for reduced speeding, there began to be significant concern that unbridled installation would soon create a cumulative slowing effect that might compromise emergency response time goals.[5] Friction developed between PDOT and the Portland Fire Bureau over the competing interests of speed reduction and emergency response time. PDOT's offers to mitigate expected slowing on calmed routes with signal pre-emption on higher classified streets assisted some projects but at a relatively high cost for no clearly defined benefit. The two bureaus agreed that there was a lack of knowledge on how much speed tables delayed emergency response equipment. In 1995, PDOT and the Portland Fire Bureau undertook a joint project to evaluate the slowing effects of speed humps and speed tables, as well as traffic circles. Five types of emergency equipment including an ambulance and heavy rescue vehicle up to engines and trucks and a rear-tiller truck were tested.

Delay Results

As expected, smaller and lighter vehicles were generally less affected by speed humps than larger and heavier vehicles. Also as expected, shorter speed humps tended to cause greater delay than longer speed tables. PDOT's testing took into account that delay caused by a particular device is a function of both the vehicle responding and the desired operational speed of that vehicle and so calculated a range of delay for each device. The delay calculated for 22-foot speed tables (10-foot tabletop) ranged from zero seconds to 9.2 seconds.[6]

Table 1. Speed Table Effect on Fire Vehicles[6]

Vehicle	Weight (lb)	Horse-power	Wheelbase	0-40 mph Accel. Time	Lowest Speed, (mph)	Min Delay 25-mph Response	Max Delay 40-mph Response
Rescue 41	na	185	11' 6"	12 sec.	34	0 sec.	1.5 sec.
Squad 1	23,170	275	14' 6"	17 sec.	24	0.4 sec.	3.4 sec.
Engine 18	34,860	185	15' 5"	19 sec.	21	0.8 sec.	5.0 sec.
Truck 1	53,000	450	21' 0"	20 sec.	22	0.6 sec.	4.9 sec.
Truck 4	53,960	450	13' 0"	22 sec.	16	1.8 sec.	7.7 sec.
Truck 41	42,100	350	37' 6"	27 sec.	14	3.0 sec.	9.2 sec.

This new information was well received by both sides. The engineers at PDOT now had hard numbers to work with instead of perceptions. Furthermore, the Portland Fire Bureau could now argue specifically how much speed humps and tables deteriorated their emergency response goals.

In the spring of 1996 a moratorium was placed on the construction of speed tables on all collector level streets and any local street that had previously been designated a fire route by administrative rule. At that time approximately fifteen pending or active projects were placed on hold. City Council then directed PDOT and the Portland Fire Bureau to work through a public process to create policy that would solve the impasse.

POLICY BASED SOLUTIONS

Rules to Live By

One method to address the concerns raised by the Fire Bureau is with a policy-based solution. In February of 1998, PDOT and the Fire Bureau completed development of a new classification of street for addition to the Transportation Element of Portland's Comprehensive Plan (now the Transportation System Plan – TSP). Primary Emergency Response Routes are designated streets that:

> "Provide a network of emergency response streets that facilitates prompt emergency response. The emergency response classification system shall be used to determine whether traffic slowing devices can be employed, to guide the routing of emergency response vehicles, and to help site future fire stations."[7]

The intent was to identify a grid of streets on which the majority of all emergency calls are accomplished and ensure that increased delay to emergency vehicles on such routes is avoided regardless of the source of the delay.

ENGINEERED SOLUTIONS

Speed Cushions

The policy-based approach addressed current projects and future projects, but left existing streets that already had speed tables and that became Primary Emergency Response (ER) routes alone. For these streets the Portland Fire Bureau agreed to continue with the status quo, and work with PDOT to determine an engineered solution. PDOT recognized the need to address the Fire Bureau's concerns on ER routes, but also had concerns that residents on newly designated ER routes would still need relief from speeding vehicles.

At the time PDOT was aware of the use in Europe of speed cushions to slow auto traffic. Speed cushions, typically made of rubber, were built just wide enough to affect autos, but not too wide so that freight vehicles, larger fire equipment and transit vehicles could straddle all or most of the device. Tests conducted in the UK found that emergency fire equipment could traverse 3-inch speed cushions 10 mph to 20 mph faster than standard speed humps used there. The same report found that cushion width and spacing affected typical driver speeds and that speeds at the devices varied from 15 mph to 26 mph.[8] Mobile Alabama has also found speed cushions to be effective at achieving 85th percentile speeds in the 24 mph to 26 mph range for the typical driver.[9] The City of Austin reported negligible delay to fire equipment as compared to typical speed humps there.[10]

The Portland Fire Bureau considered speed cushions a likely solution to delay issues associated with speed tables and often advocated for their testing. PDOT had considered speed cushions, but significant concerns remained that reducing delay for emergency equipment also meant reduced slowing for typical traffic. Speed cushion use was more common in Europe where fuel prices tend to be significantly higher that fuel prices in the U.S. This price difference was perceived to cause private vehicles in Europe to be more fuel efficient and thus smaller, with narrower wheel tracks, than typical passenger vehicles in the U.S. Narrower passenger vehicles in Europe would mean it is easier to find a speed cushion width that a fire truck or transit vehicle could straddle but that private vehicles could not. The similarity in width of the wheel track of vehicles in the United States was the driving force behind PDOT's reluctance to test speed cushions (Table 2, next page).

Table 2. Typical Vehicle Track Width

Vehicle	**Average Track Width***
Private Vehicle – Low[11]	4 ft. 2 in.
Private Vehicle – Average[11]	4 ft. 11 in.
Private Vehicle – High[11]	5 ft. 9 in.
Typical Portland Fire Engine	6 ft. 5 in.
Typical Portland Aerial Ladder Truck	6 ft. 7 in.
Typical Portland Rear-Tiller Truck	6 ft. 8 in.
Typical Tri-Met Transit Bus	6 ft. 3 in.

*Center to Center

Compounding the issue of track width was the common use of dual rear wheels for heavier vehicles like transit buses and fire trucks. Dual rear wheels in heavy vehicles mean the clear space between the wheels of large vehicles more closely matches the track width of sedans and sport-utility vehicles common in the U.S. Finding a speed cushion wide enough to slow most private vehicles and yet narrow enough to permit fire trucks and transit vehicles to pass easily, without overloading those heavier vehicles' rear axles proved difficult. Also, the use of speed cushions means there are intentional gaps, or channels, between devices in a multi-device installation (see Photo 1).

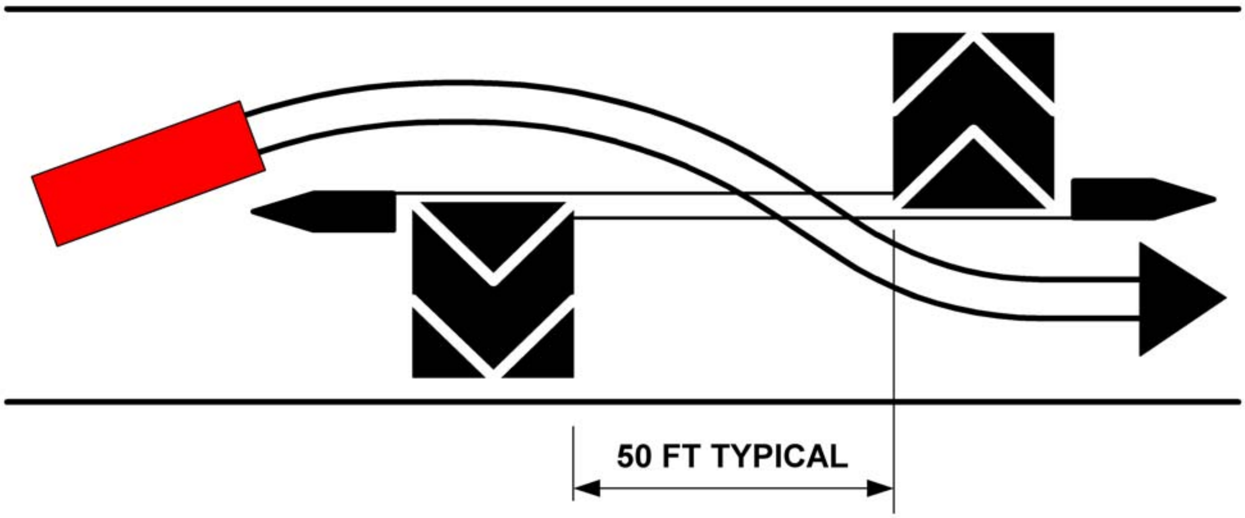
Photo 1. Speed Cushion, Lafayette, LA.

The UK study also found that 45% of drivers aimed for the gaps when traversing speed cushions and noted concern when gaps coincided with street centerlines.[12] Finally, the use of speed cushions and the need for larger vehicles to straddle the devices meant that conflicts with parked vehicles were possible, eliminating the original benefit to using speed cushions.[13]

Offset Speed Table with Median Islands

In 1997 PDOT began testing an alternative to the speed cushion concept. PDOT'S design used a standard speed table that was constructed across only half of a street. The second half of the speed table was constructed downstream of the first and in the opposing lane. As emergency equipment is able to use any portion of the roadway to accomplish a response, the space between the speed table halves permitted emergency vehicles to cross the street centerline and slalom around them in a serpentine pathway (Figure 1). Constructed with the offset speed tables were median islands on the outside approaches to deter civilian drivers from crossing the centerline. In addition, a double yellow centerline was added approaching each island and quadruple yellow centerline with raised pavement markings were added between the speed table halves. The dense pavement markings between the speed table halves gave an illusion that a median continued the entire distance. The addition of the islands and striping was done to deter drivers from mimicking the pathway emergency vehicles could take.

Figure 1. Offset Speed Table with Islands and Emergency Response Path.



Tests of the offset speed table with islands were conducted on two public streets, SE Market and SE 17th, in 1998. The testing of the offset speed hump with islands successfully demonstrated fire truck access speeds of 20-30 miles per hour through the pair of speed tables. Response delay was reduced from a maximum of 9.4 seconds for standard speed tables[6] into the 2-second range.[14] Video of the test site on SE Market showed no indication of confusion on the part of the drivers, nor any violations of drivers trying to avoid the device at any time.[14] The testing also revealed that the offset speed table with median islands has limited application. Street width must be at least 40 feet, curb to curb, to provide for the serpentine path of Emergency Equipment and parking removal is often necessary opposite of each speed table half (see Figure 1). Additionally, where the street is less than 40 feet, transit drivers and other wide vehicle operators may feel uncomfortable traveling between the island and parked cars. Where a 12-foot travel lane between the island and parked cars is not possible, additional removal of parked vehicles adjacent to the island on the speed table side might also be necessary. Many of Portland's Neighborhood Collector streets are less than 40 feet and coincide with Primary Emergency Response Routes. Also, for traffic calming to be considered on Neighborhood Collector streets in Portland, they must have a minimum of 75% residential zoning. Under such conditions, on-street parking demand is generally high, making parking removal politically difficult.

Offset Speed Tables without Median Islands

In 2001 PDOT and the Portland Fire Bureau initiated another round of testing to determine if a speed cushion like device could effectively slow traffic while reducing response delay for emergency vehicles. The concept was to use the standard offset speed hump layout without the islands and adding a speed cushion like channel. In the test a channel was placed through a standard half-street speed table, aligned near the center of the travel lane. The object was to permit a fire truck to place the left side just over the centerline while aligning the right-side wheels with the channel. The hope was that providing the channel would effectively nullify the speed table's effects on large fire equipment.

PDOT constructed a prototype device at the Fire Bureau's training facility (Photo 2). This is a controlled area not subject to general traffic and permitted a variety of vehicles to test the device while data was collected. The primary purpose of this test was to determine what benefit the channeled speed table design provided for emergency vehicle response time. This testing also assisted in answering concerns of PDOT over driver control questions as well as refining the design and evaluating constructability issues.

Photo 2. Offset Speed Hump with Channel Test Object – Looking Upstream.

The test device was constructed at Station 2 the week of July 16, 2001. The test object was a standard 22-foot speed table with 6-foot parabolic approach ramps and a 10-foot flat section with a maximum height of 3 inches. A channel was constructed offset from the centerline resulting in a 6-foot 3-inch wide cushion-like object that emergency equipment could straddle. The edge tapers for the channel and centerline edge were constructed with a 1:2 slope. Formal testing, using eight vehicles, was conducted on July 23, 2001. Each vehicle was driven over the device twice with drivers directed to aim for the channel. For the first run drivers were directed to attain 25 mph before crossing the speed table. For the second run the target speed was 30 mph. In past tests the typical speeds of fire trucks and engines crossing a standard 22-foot speed table varied from 14 mph to 21 mph.[6] The majority of delay at the standard 22-foot speed table is due to the larger fire vehicle's slow acceleration. Attaining typical crossing speeds above 25 mph with the new design would represent a significant reduction in delay for emergency response and was the chosen target speed for a successful test. Each vehicle successfully traversed the test device near or above 25 mph as shown in Table 3.

Table 3. Emergency Vehicle Speed over Offset Speed Table with Channel

Vehicle	**Weight**	**Maximum Speed At Speed Table (mph)**	
		First Run 25-mph Goal	**Second Run 30-mph Goal**
2000 Ford Crown Victoria Police Interceptor	3900 lb.	24	30
2000 Chevrolet Police Camaro	3500 lb.	25	30
2000 Kawasaki KZ 1000 Motorcycle	600 lb.	>26	30
1998 Ford Van – Police Photo Radar Unit	4,700	>25	>30
Fire Rescue 2 - 1994 Ford Fire Rescue	10,500	>25	>30
Engine 2 - 1995 H&W Fire Engine	38,150	25	30
Fire Truck 2	na	30	35
Truck 13 - 1994 Simon LTI, Rear Tiller Fire Truck	58,000	>25	30

* The police vehicles did not attempt to use the channel

Drivers that participated in the testing expressed very favorable comments regarding the channel design and the significant reduction in discomfort for personnel, though concern remained about citizens that might stop on a speed table when an emergency vehicle approaches. The Portland Bureau of Maintenance, who constructs nearly all speed tables in Portland, noted the narrower section between the channel and centerline was labor-intensive to construct and may double the cost of construction over a typical speed table placed with the aid of machines.

The testing also confirmed that the original device proposal might be ineffective for speed reduction. As previously stated, placement of the channel so that the majority of drivers straddle the channel is critical to achieving the desired slowing effect for typical traffic. As originally proposed, and due to current vehicle dimensions, PDOT was unable to identify a channel location that ensured the success of the proposed device for slowing traffic. By placing one set of wheels in the channel a sedan size vehicle driven over the speed table attained a speed of 30 mph without significant discomfort to the driver.

However, the determination that a channel greatly reduced the effectiveness of the speed table for typical traffic even though only one set of wheels could be placed in the channel led to a revised design. In the revised design a half-street speed table without a median or channel would be evaluated. The new proposal would require emergency equipment to cross the standard speed table profile with the right side of the vehicle, but the left side of the vehicle could cross just over the centerline and avoid the speed table profile completely. With the channel removed, vehicles operated by the general public would encounter a standard 22-foot speed table profile, ensuring continued speed reduction. Another advantage to a full half-street speed table is that it can be built faster, and at lower cost, since more of the device could be constructed with mechanical equipment.

A second series of field tests using only the four Fire Bureau vehicles were conducted on July 26, 2001. The second round of testing included target speeds of 20 mph, 25 mph and a free run where the driver picked the speed. The Fire Bureau vehicles ran the same course again, and radar recorded their top speeds while traversing the speed table as follows:

Table 4. Emergency Vehicle Speed With Only Right Half on the Speed Table.

	Maximum Speed At Speed Table (mph)		
Vehicle	**First Run 20-mph Goal**	**Second Run 25-mph Goal**	**Third Run Driver Choice**
Fire Rescue 2	>20	<25	>30
Fire Truck 2	>20	>25	>30
Fire Engine 2	>20	>25	>30
Fire Truck 13, Rear Tiller	>20	>25	>30

As can be seen, the modified design continued to provide excellent travel speed as compared to typical speed table speeds of 14-21 mph for Fire Bureau Equipment.[6] Drivers that participated in the testing continued to express positive comments about their comfort using the speed table as modified.

NEXT STEPS

Early Live Testing

The nearby City of Beaverton installed offset speed tables without islands on SW 87th-Birchwood-Laurelwood in the summer of 2003 (Photo 3, next page). Offset speed tables were chosen due to the designation of the street for emergency response. Before construction of the speed tables the 85th percentile speed was measured at 34 mph in a 30-mph zone with 25% of drivers exceeding the posted speed. After construction the 85th percentile speed reduced to 30 mph with 15% of drivers exceeding the posted speed. Vehicle volume on the street reduced from and average of 5800 vehicles per day (vpd) to 5400 vpd. The offset speed tables were originally constructed with only pavement striping to communicate to drivers to remain on their side of the street due to the weather. Subsequent to construction Beaverton received complaints from local residents about driver circumnavigation of the offset speed tables by crossing the centerline. The City of Beaverton added raised pavement markers with inset reflectors to deter such behavior (see Photo 4) after the weather warmed up in 2004. The City of Beaverton reports that complaints regarding centerline violations are no longer common from local residents.

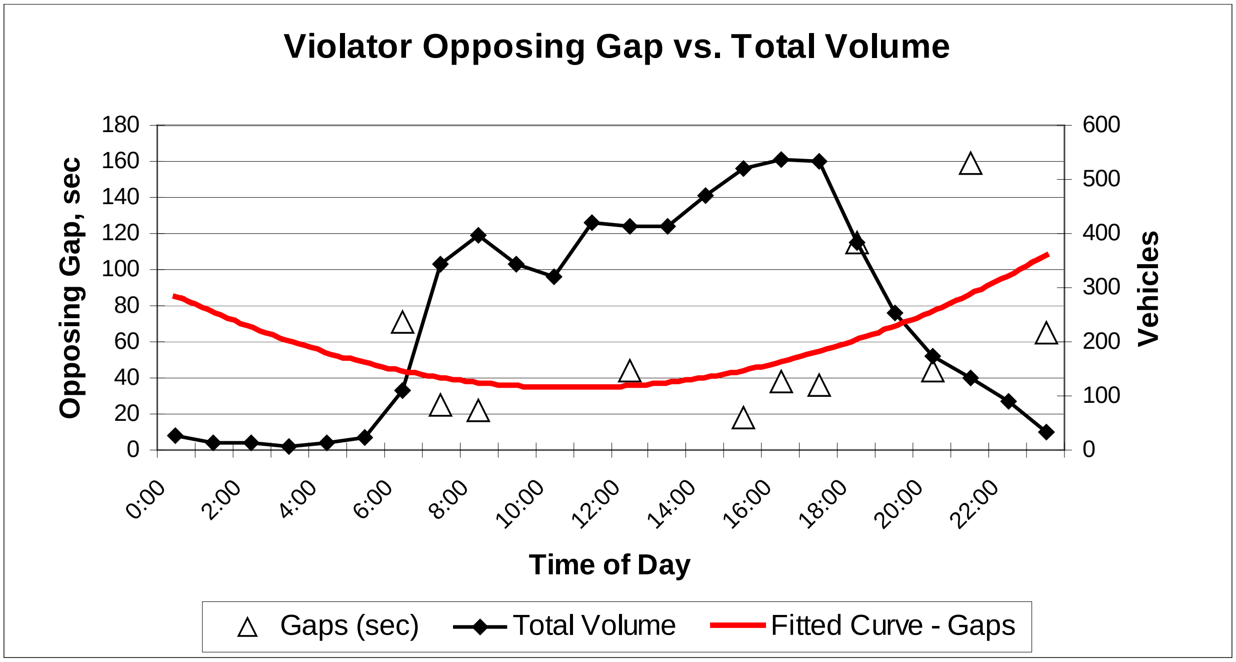
Photo 3. Beaverton Offset Speed Hump – SW 87th Avenue.

Photo 4. Beaverton Offset Speed Hump Centerline RRPMs.

PDOT Testing

It is expected that the offset speed table will be self-regulating in regards to centerline violations and such self-regulation is sensitive to opposing traffic volume. As opposing volumes increase fewer drivers likely to violate a double yellow centerline will do so (see graph 1). PDOT collected video at the Beaverton site to determine the frequency of centerline violations. Approximately 13 vehicles in a 24-hour period violated the centerline to some extent, either completely or partially avoiding the offset speed tables. This represents a violation of 0.22% of the total population of drivers. The average length of time a driver was within a portion of the opposing lane (exposure) during such maneuvers was 2.88 seconds with a standard deviation of 1.13 seconds. The opposing headway gap, the length of time before the next opposing vehicle passed the offset speed table after a violation occurred, averaged 22 seconds with a standard deviation of 10.43 seconds. The exposure and opposing headway analyses are conservative in that data corresponding to opposing gaps in excess of 60 seconds (5 of the 13) were discarded.

Graph 1. Violations versus Traffic Volume



FUTURE RESEARCH

With a speed table that is only constructed to the centerline of a street comes the possibility that civilian drivers will mimic the pathway intended only for emergency service personnel. Opposing vehicle traffic plays a part in making sure drivers stay on their side of the road and slow down. Unknown at this time is what threshold of traffic volume is the minimum needed to ensure that drivers will remain on their side of the street. PDOT is currently seeking a suitable City street to advance testing the offset speed table concept.

SUMMARY

From the outset PDOT has had concerns that efforts to nullify the effect of speed humps for emergency response, as with speed cushions, would also render them ineffectual at reducing speeding. Testing conducted by PDOT and the Portland Fire Bureau successfully showed the ability of the offset speed table design to reduce emergency vehicle delay, especially the largest trucks that normally suffer the greatest delay. A reduction in maximum delay from 4.8 seconds at standard speed tables where the target response speed is 30 mph to the typical 2 second delay at offset speed tables represents a better than 50% reduction in emergency vehicle delay. PDOT is confident that the offset speed table will continue to reduce speeding as effectively as standard speed tables. PDOT was also successful in identifying minor adjustments to the final design to improve constructability. The design changes discussed in this paper, and the cooperation between PDOT and the Portland Fire Bureau to explore a compromise that avoids an all or nothing choice has gone a long way to solving the issue of emergency response delay caused by speed tables.

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