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# SPEED CALMING USING VERTICAL DEFLECTIONS IN ROAD ALIGNMENT

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## Abstract:

In densely urbanized areas with intensive land uses, traffic calming is a vital safety countermeasure to avoid violation of permitted speed-limits in hazardous areas such as; approaches of un-signalized at-grade intersections and upstream of surface pedestrian-crossings at or nearby densely land-uses such as; schools, hospitals, worship houses, etc. Previous researches showed that speed calming is usually done by either horizontal or vertical deflections in road alignments. Horizontal deflections in road alignment could be achieved through narrowing carriageway width, adopting horizontal alignment to prevent over speed, etc. while vertical deflections in road alignment could be achieved through instillation of speed humps upstream to the required speed calming or temporary work-zones locations. This paper focuses on determining actual traffic performance up- and down-streams of speed calming countermeasures using vertical deflections in road alignment (humps and speed tables) to study the influence of their physical and geometric characteristics on traffic performance, in terms of speed profile and also to extract some guidelines for their most suitable locations.

## Keywords:

Road alignment, traffic in Urban areas, speed calming, traffic flow, speed humps, road safety

## Introduction and back ground

During the last decades, roads and streets have been widened and straightened to accommodate more and faster motorist traffic. These changes facilitate driving but often degrade conditions for walking, cycling, and for nearby dense urbanized a reas. Even during the early years of motor vehicle use some neighborhoods resisted increased traffic [1], and this opposition has increased in recent years [2]. Traffic calming is the name for road design

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strategies to reduce and control vehicle speeds and volumes [3]. There are many potential traffic calming strategies. Summaries of these commonly used traffic calming strategies and devices, including suitable applications and impacts are presented in Table (1). It is important to mention that traffic calming projects often involve several countermeasures ranging from a few minor changes to neighborhood streets to major rebuilding of a street network. Impacts range from moderate speed reductions on densely urbanized areas, to arterial design changes[4], and residential streets with minimal traffic speeds [5]. Traffic calming is becoming well accepted by transportation professional organizations and urban planners [6]. Some people accept traffic calming, some do not accept it, and others have mixed feelings. Advocates argue that traffic calming protects residents, pedestrians and bicyclists from externalities imposed by motor vehicle traffic, and allow residential and commercial stre ets to better balance their multiple uses. Critics argue that it wastes resources, that it imposes an unfair burden on drivers, that it simply shifts traffic impacts from one street to another, and that it does more harm than good[7]. Many of the concerns about traffic calming relate to specific devices, such as speed humps, rather than the general concept of changing street designs to reduce traffic speeds. These can often be addressed by expanding the range of strategies considered and using the most appropriate strategy in each particular situation. This paper provides a comprehensive framework for evaluating traffic performance up - and downstream of speed humps, and try to determine the influence of both physical and geometric characteristics of speed humps on traffic performance in terms of speeds and volumes. Cat-eye reflectors are retroreflective safety devices that can be used effectively in road marking to provide directional guidance on roadways. In Egyptian, the effectiveness of using transverse cat-eye reflectors in the driving lane as warning and traffic calming devices is examined and the effectiveness of Cat-eye reflectors as traffic calming measure and/or warning device has been assessed in this research through field measurements of speed and in -depth interviews with different drivers[8]. The results show that cat-eye reflectors are not effective in reducing speeds in highways. They are, however, effective in reducing speeds in local roads and suitable for streets with operating speeds of up to 50 km/h. In highway test sites, the average speed was reduced from 67.41 km/h upstream from the device location to 63.56 km/h at the device location, approximately 5.7 percent, and average 85th percentile speed was reduced from 80.43 km/h to 77.79 km/h, approximately 3.3 percent. In local roads, the results show that the average speed was reduced from 44.13 km/h upstream from the device location to 15.6 km/h at the device location, approximately 64.6 percent. The average 85th percentile speeds was reduced from 44.65 km/h to 16.2 km/h, approximately 63.4 percent. The results show that the effect of the cat-eye reflectors is limited to a short range (30 m to 60 m) from the device location. In Netherlands, traffic calming had its genesis in the form of (woonerfs) or residential precincts, designed to limit the mobility of motor vehicles in neighborhoods [9].

Table (1) Traffic calming strategies and devices [10]

| Type | Description | Applications | | Impacts | |
|---|---|---|---|---|---|
| | | Arterials | Local | Volumes | Speeds |
| Speed limits | Reduce speed limits. | √ | √ | Yes | Yes |
| Speed alert, | Radar-clocked traffic speeds displayed to drivers. Strong | √ | √ | No | Yes |

| | | | | | |
|---|---|---|---|---|---|
| enforcement | speed limit enforcement. | | | | |
| Vehicle restrictions | Limiting vehicle types (trucks) or users (residents only) on specific road. | √ | √ | Yes | No |
| Warning signs & gateways | Signs & gateways indicating changing road conditions, traffic calming, in residential or commercial districts . | √ | √ | No | Yes |
| Speed tables, raised crosswalks | Ramped surface above roadway, 7-10 cm height, 3-6 m length. | With cautions | √ | Possible | Yes |
| Median Island | Raised island in the road center (median) narrows lanes and provides pedestrians with a safe place to stop. | √ | √ | No | Yes |
| Canalization islands | Raised islands that forces traffic in a particular direction, such as right-turn-only. | √ | √ | Possible | Yes |
| Speed humps | Curved 7-10 cm height and 3-4 m length. | V | v | Possible | Yes |
| Rumple strips | Low bumps across road make noise when driven over. | √ | √ | No | Yes |
| Mini-circles | Small traffic circles at intersections. | | √ | Possible | Yes |
| Roundabouts | Medium to large circles at intersections. | √ | | | Yes |
| Pavement treatments | Special pavement textures (cobbles, bricks, etc) and marking to designate special areas. | √ | √ | Not likely | Yes |
| Bike lanes | Marking bike lanes and narrowing traffic lanes | √ | √ | No | Possible |
| Curb extensions (bulbs, chokers) | Extending curb a half-lane into street to control traffic and reduce pedestrian crossing distances. | √ | √ | Possible | Yes |
| "Road diets" | Reducing the number of traffic lanes | √ | | Yes | Yes |
| Lane narrowing, "pinch points" | Curb extensions, planters, or centerline traffic islands that narrow traffic lanes. Also called "chokers." | √ | √ | Not likely | Yes |
| Horizontal shifts | Curving or shifting the centerline of traffic lanes. | √ | √ | No | Yes |
| Chicanes | Curb bulges or planters (usually 3) on alternating sides, forcing motorists to slow down. | | √ | Possible | Yes |
| Two-lanes narrow to one-lane | Curb bulge or centerline island narrows two-lane road down to one-lane, forcing traffic for each directions to take turns. | | √ | Possible | Yes |
| Semi-diverters, partial closures | Restrict entry/exit to/from neighborhood. Limit traffic flow at intersections. | √ | √ | Yes | Possible |
| Street closures | Closing off streets to through vehicle traffic at intersections or midblock. | | √ | Yes | Yes |
| Stop signs | Additional stop signs such as 4-way-stop intersections. | | √ | Possible | Yes |
| New guidelines for street design | Streets with narrower traffic lanes, shorter blocks, T-intersections, and other design features to control traffic speed and volumes. | √ | √ | Yes | Yes |
| TDM | Various strategies to reduce total motor vehicle use. | √ | √ | Yes | No |
| Others | Very low-speed residential streets with mixed vehicle and pedestrian traffic | | √ | Yes | Yes |

## Research methodology

This paper focuses on studying the influences of both physical and geometric features of speed humps and speed tables, installed as speed calming countermeasures on densely urbanized roads in Cairo, on traffic performance in terms of traffic speeds. To achieve the planned objectives, the research methodology showed in Figure 1 is followed.

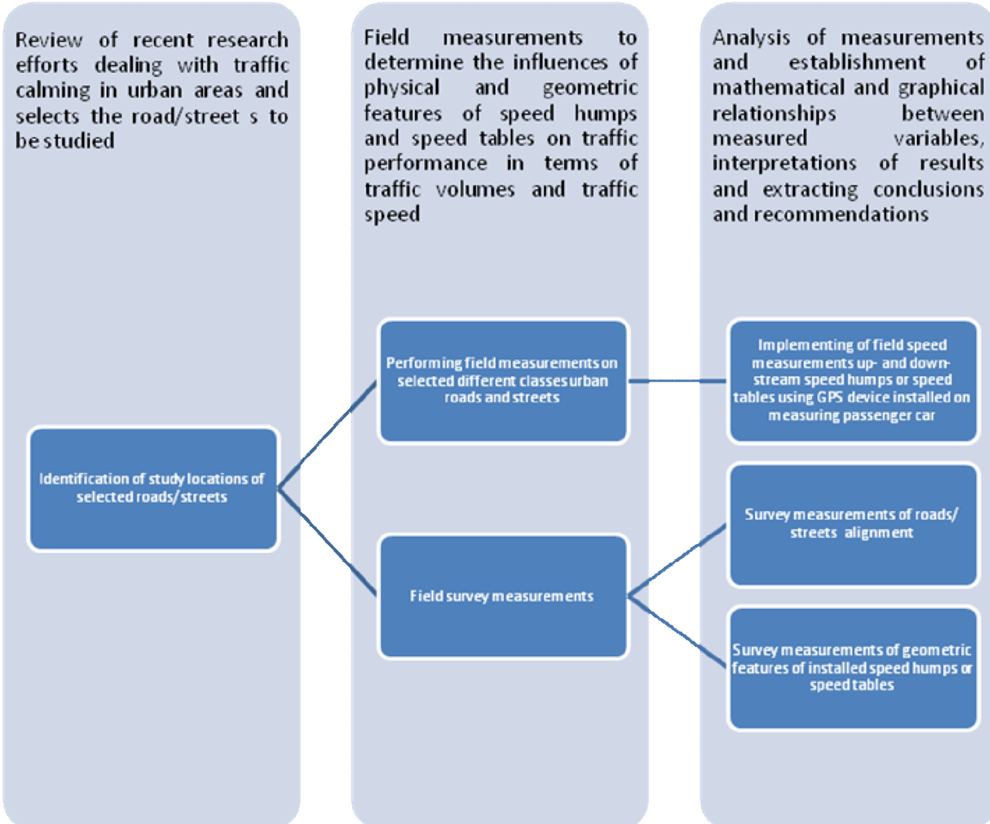


Figure (1) Research methodology flowchart

## Features of the used GPS device in data collection course

Figure (2) shows the used GPS Nexteq GPS device, Powered by Nexteq Freedom™, in measuring speed profile up and down stream of selected physical traffic humps and speed tables. Nexteq Freedom™ is a next generation technology which allows for unprecedented positioning performance from a single autonomous receiver. The Nexteq T5 is the first commercially available high precision autonomous single -frequency GPS handheld. Powered by Nexteq's Freedom™ technology, it redefines the limits of autonomous GPS.

**ACCURATE**: 40 cm positioning accuracy with no convergence time.
**FULLY-FEATURED**: The Nexteq T5 is a feature-rich handheld with a touch screen LCD, MicroSD slot for expandable storage, 1.3 megapixel camera with microphone, Bluetooth and wireless GPRS data communication.
**DATA CONNECTIVITY**: With its available GPRS communication module, the Nexteq T5 can be used as part of Network RTK or CORS for further improvements in positioning accuracy. The T5 can also upload collected data in real-time back to the office.
**COMPATIBLE**: Data collected by the Nexteq T5 is compatible with all other Nexteq T series products and also with industry standard formats.


Figure (2) the used Nexteq GPS device in measuring speed profile

## Data collection

To achieve the desire research objectives, an intensive data collection course is performed on selected urban roads using the previously mentioned GPS device for online continuous identification of trip route in terms of; route coordinates and road levels, and vehicle speeds.

In collecting speed profile data, a set of selected urban streets in New Cairo city with good pavement surface on which speed humps or speed tables are installed in straight links (segments). The free flow speed of these streets is 90 km/h. Free flow speed is the free speed at very low traffic volume i.e. there is no influence of traffic volu me on driver's speed.

Table (2) shows the physical characteristics of the traffic humps and speed tables on the surveyed roads.

Table (2) shape of humps and speed tables on streets under study

| Number | Shape | Length (cm) | Height (cm) |
|---|---|---|---|
| 1 | Parabolic hump | 210 | 12 |
| 2 | Parabolic hump | 380 | 5 |
| 3 | Parabolic hump | 250 | 20 |
| 4 | speed table | 500 | 13 |
| 5 | speed table | 500 | 13 |
| 6 | speed table | 500 | 13 |

Table (2) shows that three parabolic humps and three speed tables are tested on urban streets in New Cairo city. These streets have the same free flow speed (90 km/h) and have good pavement surface. The speed humps and speed tables are on selected streets are located on straight segments and flat grades (±0.3 to ±0.5% longitudinal grades) and away from vertical curves or horizontal bends to ensure that no other parameters affecting the measured speed profiles such as consistency of road alignments, superelevation at road bends, sight distance, etc. Also, speed profile is measured in daylight time in normal working day with almost free flow condition and clear dry weather condition with air temperature of about 19°C

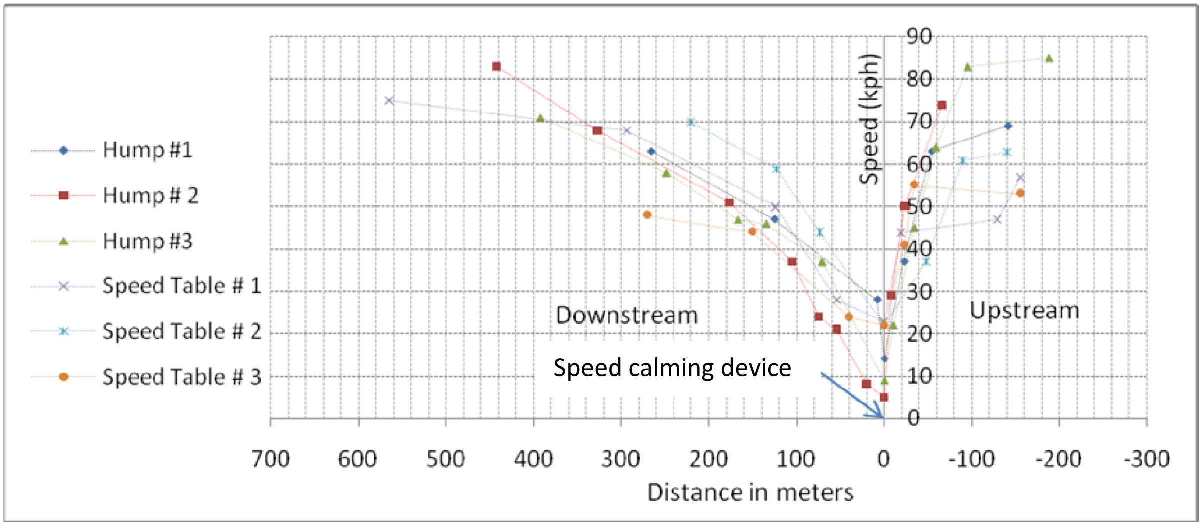


Figure (3) speed profile up and downstream three traffic humps and three speed tables

Figure (3) shows the measured speeds at different distances up and downstream of three speed humps and three speed tables. The physical characteristics of these speed humps and speed tables are in Table (2). Each data series in Figure (3) shows the measured speed profile up and downstream of each speed calming device (speed hump or speed table). F igure (3) shows also that:

- The deceleration up stream traffic calming device starts at distances varying from 100m to 60m upstream the speed hump or speed table understudy. That mean. The deceleration started after recognizing the upstream of the speed cal ming devices through road signs and retroreflective road marking and the deceleration distance vary from 60m to 100m.
- The reduced speeds (at distance 0 on Figure 3) reflect the measure speeds at the position of traffic calming device (speed table or speed hump). These speeds vary from 5 km/h to 28 km/h. There was no clear significant correlation between the speed on traffic calming device and its shape (length and height).
- The acceleration downstream traffic calming device occurred over a relatively longer distances (250m to 530m) compared with the deceleration upstream the traffic

calming device(60m to 100m). This result reflects that vehicles require longer distance to accelerate their speed to the normal driving speed.

## Speed profile models for upstream and downstream traffic calming devices

Figure (3) showed that speed behavior upstream speed calming devices (deceleration part) is different from speed behavior downstream speed calming devices (acceleration part). Therefore, two different speed models are built to show the speed behaviors up and down streams traffic calming devices. In building these models speed profile data for up and down stream all measured devices are merged together, as no significant differences between speed behavior up and downstream speed humps and speed tables.

Mathematical models are built to fit the measured speeds at different distances up and downstream of the traffic calming devices. Also, a boundary condition is set so that the maximum speed up or downstream the traffic calming devices is the street free flow speed.

Speed model for upstream traffic calming device is given by:

$$V_u = 90-74*e^{(-0.017\,x)} \ldots\ldots\ldots\ldots\ldots (1)$$

Coefficient of determination ($R^2 = 0.94$)

Where:

$V_u$ is the speed at distance x upstream the traffic calming device

X is the distance upstream traffic calming device

Note that the constant 90 is the free flow speed of the tested streets, i.e. the speed at any distance upstream the speed calming is the free flow speed minus the speed reduction value.

Speed model for downstream traffic calming device is given by:

$$V_d = 90-74*e^{(-0.0038x)} \ldots\ldots\ldots\ldots\ldots (2)$$

Coefficient of determination ($R^2 = 0.91$)

Where:

$V_d$ is the speed at distance x downstream traffic calming device

X is the distance downstream traffic calming device.

Figure (4) showed the two built models as well as the merged speed profile data used in building these models.

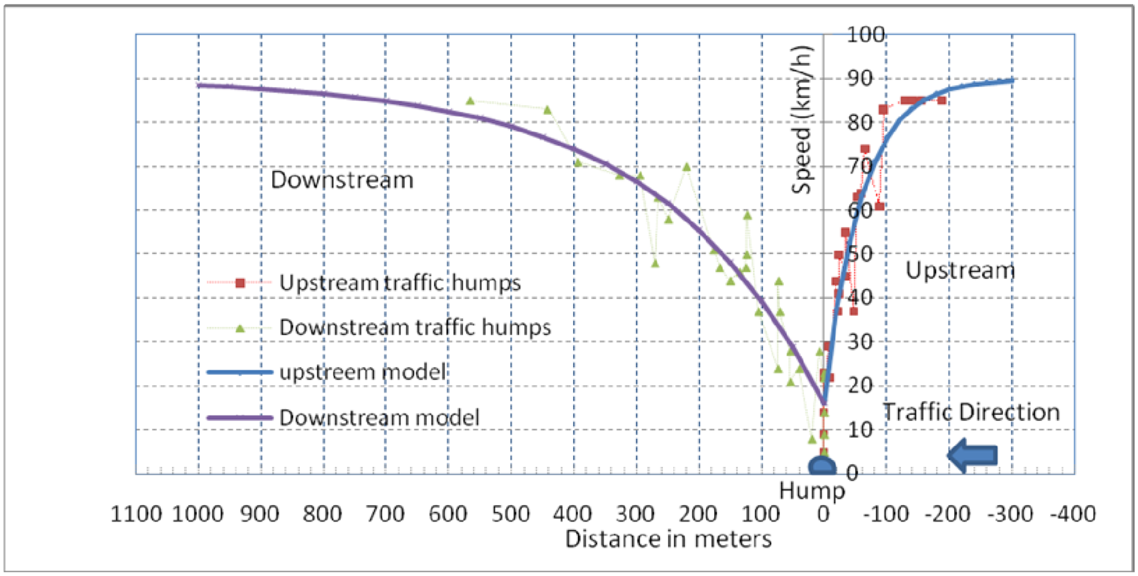


Figure (4) speed profile models for up and down stream traffic calming devices on urban streets in new Cairo city.

To discuss speed behavior up and downstream of traffic calming devices, speed ratio of up and downstream to free flow speed as well as speed ratio of upstream and downstream speeds are presented in Figure (5).

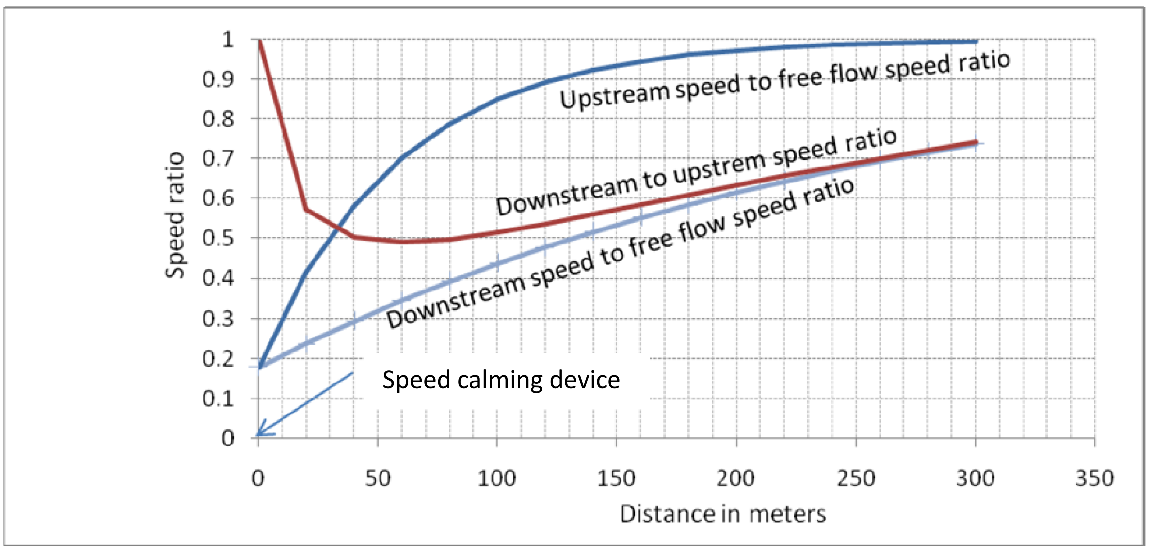


Figure (5) ratio of up and downstream speeds to free flow speed and ratio between upstre am speeds to downstream speeds at different distances from speed calming device

The following important findings can be extracted from Figures (3, 4):

- Speed behavior upstream traffic calming device is different than speed behavior downstream traffic calming device.
- The speed profile up and down stream traffic calming are not symmetric where deceleration (upstream calming device) occurs over shorter distance while acceleration (downstream traffic calming) occurs over longer distance.
- Up and down stream speeds at speed calming device are equal in magnitude (about 20%) of the free flow speed.
- Upstream speed to free flow speed ratios are higher than downstream speed to free flow speed ratios, as acceleration occurs over longer distances. But these ratios are equal at the traffic calming device (at distance 0).
- The downstream speeds are almost 0.5 of the upstream speed ad distances from 50 to 100 m from the speed calming device.
- Downstream speed to free flow speed ratios have almost the same values of downstream to upstream speed ratios for distances greater than 250 m for the location of traffic calming device.

## Conclusions and recommendations

- Speed calming devices are effective in reducing traffic speed on urban streets to about 20% of the free flow speed
- No clear significant difference between tested speed humps and speed tables on the measured speed reduction at speed calming device
- Speed models up and down stream traffic calming devices are not symmetric as the deceleration (upstream) has different behavior compared with the acceleration (downstream) speed calming device.
- Acceleration downstream speed calming device occurs over longer distance. In our study, to accelerate to free flow speed downstream speed calming device a distance from 550m to 900m is required. Therefore, installing successive speed calming devices at short distance will prevent the vehicle form reaching the free flow speed after passing the first speed calming device or even may lead to deceleration after starting the acceleration and in turn lead to reduce platoon speed and with high traffic volume will be a bottleneck causing traffic congestion in the upstream, increasing fuel consumption, pollution and raise driver stress.
- Traffic warning signs and retroreflective road marking upstream speed calming devices are of great importance particularly in night driving and the distance of these warning signs and marking will depend on free flow speed. For ours case with 90 km/h free flow speed a distance from 150m to 100m upstream speed hump or speed table is optimum for starting warning signs and road marking.
- The traffic calming device itself should be painted with retroreflective durable paint to be visible in night driving.

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