AN AUDIT ON APPLICATIONS OF TRAFFIC CALMING DEVICES IN KORKUTELI-TEFENNI ROAD DISTRICT

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ABSTRACT: Traffic is defined as the state and movement of pedestrians, animals, goods and vehicles. Traffic cannot be defined as a system of roads in which only flow is directed, because traffic must be harmonized. One of the ways to do this is traffic calming implementation which are applications designed to calm traffic and decrease crash rates. The main goal is to reduce speed of vehicles, increase pedestrian and cyclist safety, decrease noise of traffic, provide a smooth traffic flow. In this study, the data was collected from an official website presenting traffic volumes of highways. Accordingly, considering trade-offs and location audit, the most convenient site was chosen in Korkuteli-Tefenni road district with the help of traffic calming devices and their utility attributes. Then, the most appropriate horizontal traffic calming as center blisters or slow points (chicanes) that effectively calm traffic was applied. According to our analysis, the results basically show that slow points are more operative and advantageous than center blisters for the particular location selected. Our study also proved that, compared to the literature, because while center blisters remain ineffective on the traffic volume, slow points can reduce the average traffic volume up to a certain degree.

Keywords: *Traffic calming, traffic flow, slow points, center blisters.*

1. INTRODUCTION

There is no generally accepted definition of traffic calming. Reducing the possibility of shooting pedestrians and cyclists by reducing the speed of motor vehicles is the fundamental tenet of traffic calming, and when a collision comes off, the effect of the accident and the severity of injuries should be reduced. Besides, the probability of death or serious injury after collisions are less at low speeds statistically. In fact, traffic calming measures aimed at decreasing the speed of motorized traffic were confined between residential areas and neighbourhoods. Then, it was thought that the principle of traffic calming in residential areas should be applied in a wider area in order to increase road safety so, it was insufficient to apply only on an individual street. In addition, traffic calming applications that have an aesthetic appearance on the streets are used in many developed countries. These traffic calming applications can reduce the noise pollution caused by traffic problems. General objectives of the US Department of Transportation's traffic calming principles: 1) decreasing the speed of vehicles, 2) making neighbourhoods and streets more liveable, 3) providing the perception of reliability for pedestrians and cyclists (non-motorized users), and 4) decreasing the requirement to use residential streets to ensure uninterrupted vehicle traffic (USDOT, 2019).

Although traffic calming practices are widely and effectively used in developed countries, they are not utilizing common in Turkey, and the desired yield could not be obtained. The lack of adequate research and practice has created such problems. In addition, unfortunately, only vertical traffic calming is known in our country when it comes to traffic calming principles. In conclusion, in this article, the features, application areas and applicability of horizontal traffic calmings will be discussed. And some solutions will be presented to improve traffic calming practices in Antalya.

Firstly, in this research, the historical past of the traffic calmings will be explained. Secondly, features of horizontal traffic calmings and how they are used will be introduced and formulations will be shown. Then, the most appropriate horizontal traffic calming will be decided. And the appropriate horizontal traffic calming will be applied to the Korkuteli-Tefenni road. Finally, the results and conclusions of the situation will be noted.

2. HISTORICAL OVERVIEW

Traffic calming is a project designed to ensure that human communities in streets are together and safe traffic calming serves some major crucial aims. Ensembles (as pedestrians, runners, cyclists, motor vehicle passengers, families and children) must be served safety and sufficiently. Van Schagen (2003) pointed that the Organisation for Economic Co-operation and Development report on vulnerable road users demonstrate the beginning of the traffic calming concept. Also, traffic calming uses methods for decreasing the effect of vehicle traffic by decelerating speed, or exactly calming (Galante et al., 2010; Moreno and García, 2013).

Between 1960s and 1970s, becoming to possessing car was increased rapidly. For undefended road users and residents of built-up areas, unreliable roads were built ineffectively with aim of poising the growing car traffic. With examples, pavements were constricted towards additional car lanes, the areas in street, reserved for pedestrians and cyclists were occupied by parked vehicles gradually. As a result, it was obvious that increased car ownership would pose major problems. At the end, researches have been initiated to develop private vehicle traffic in a controlled manner. In the 1960s, the locution of traffic calming was spawned primarily despite the tenet of traffic calming was commenced. Besides in the 1960s, due to the woonerf or living spaces projects, the traffic calming began in the Netherlands. The woonerf is a street or road, and pedestrians and cyclist possess juridical precedence over motorists, in the woonerf. Increasing safety of pedestrian, bicycles, and motor vehicles is a significant goal, and some traffic calming techniques have been used to achieve this aim (Nature's Path, 2020).

Under the name of Verkehrsberuhigung, Germany began to work as traffic calming in the late 1970s. When it extended to Canada, Australia, and other European countries some ensembles in the United States started to use traffic calming tenets in the late 1970s. At the same time, such projects reduced accident and injury rates by 20% to 80%. Also, Ashton and Mackay (1979) stated in their studies that the risk of serious injury is very low for unprotected road users (such as pedestrians and cyclists) in accidents below 30 km/h. Based on this information, Van Schagen (2003) pointed that because 30 km/h sign would not be enough, inexpensive speed-reducing measures could support the speed limit of 30 km/h. Then, after the 1980s, many European countries set a 30 km/h speed limit for residential areas. For example, a sustained demonstration took place in six German towns in the 1980s. In relation to this, Ewing (1999) implemented many measures. For instance, 30 km/h speed limit was set to many regions, speed tables, chicanes, pinch points were introduced to many streets and collectors, and many streets were turned into two-way streets. Nowadays, some traffic calming applications that are not available in many developed countries are available on Australian streets. According to claim of Ewing (1999), Australia is the leader in traffic calming applications and in the usage of modern roundabouts.

3. METHODOLOGY

The main purpose of traffic calming is to prevent motor vehicle traffic from settlements. To accomplish this, some conditions must be met. So, reducing traffic volumes and traffic speeds are the main task of traffic calming. At the same time, another purpose of traffic calming is increasing road safety, especially the safety of pedestrians, cyclists, shortly non-motorized users. Mao and Koorey (2010) researched the impacts of traffic calmings in Christchurch in New Zealand, and at the first step, prediction of Annual Average Daily Traffic was evaluated and defined with the following processes. Firstly, they defined the number of weeks (1-52) where traffic is counted for 1 year. Then, they defined the weekly average daily traffic (WADT) according to holiday factor and counted week. Later, they evaluate the Annual Average Daily Traffic (AADT) = week factor * holiday factor (if it is characterized) * WADT (Weekly Average Daily Traffic). After these processes, the traffic volume growth rate must be evaluated and judged annually. In the last step, the Traffic Plan network should be established.

Another application for calming is the use of center blisters. Center blisters is one of the applications used to slow down speed in traffic. Minnema (2006) stated that center blisters are commonly applied to break long lines of sight, especially on public transportation routes as other calming measures are not suitable. Minnema (2006) applied a study in the New South Wales, and center blisters showed an impact of 85th percentile speed decrease by 38% to 44%. In Table 1, effect of speed reducing center blisters is given.

Table 1: Center blister – Before and After speed (Minnema, 2006)

Location	Before 85th percentile (km/h)		After 85th percentile (km/h)	
	N/W	S/E	N/W	S/E
Artarmon Rd Willoughby	70	71	43	40
Flinders Rd, Bankstown	75 (mid device)		62 (mid device)	

Furthermore, other studies on center blisters have also been carried out. In Melbourne, Australia, central blister traffic speed reduction tests have been conducted in 9 different regions. 10 m distance is used as a criterion in the chart. Jurewicz (2009) found that the center blisters could not reduce the traffic speed as much as roundabouts and center blisters reduced traffic speed by 8% or 14% in his studies. In Figure 2, it is shown that when vehicles approach the center blister, their speeds reduce.

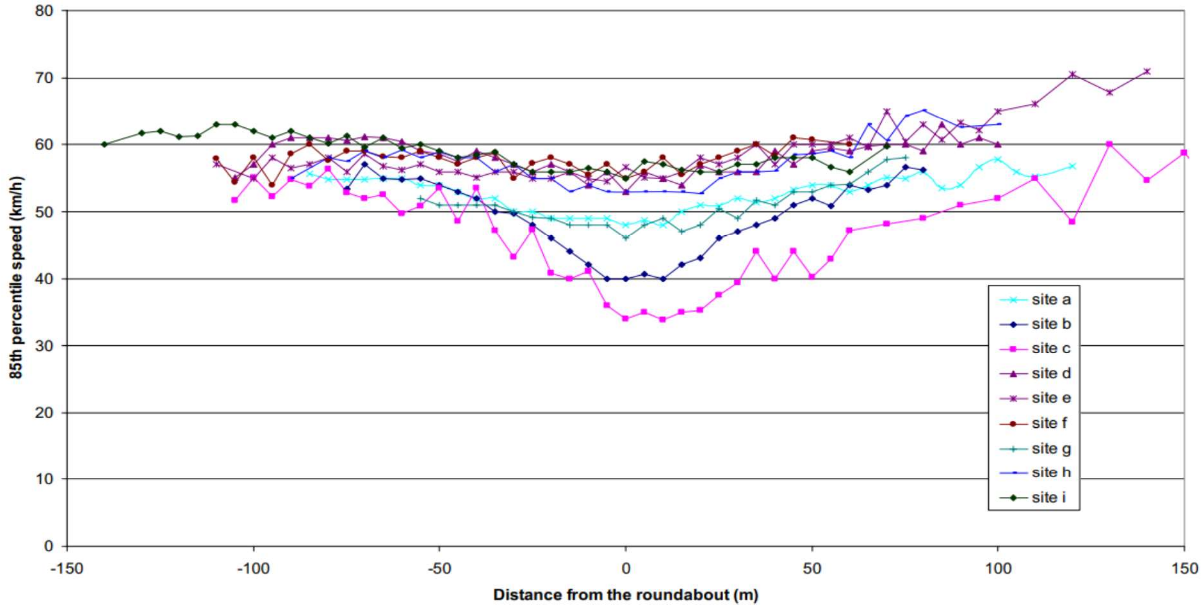

Figure 2: Center blister islands – 85th percentile speed profiles for the trial sites (Jurewicz, 2009)

Jurewicz (2009) stated that the average speed decrease was 6 km/h which was 9.7% of the average 85th percentile approach speed (V_{app}) by excluding sites b and c because their operations were dissimilar than the others. For example, sites b and c had lower radius of maximum travel path (R_{mtp}) and lower speed decreased speed owing to center blisters (V_{min}). In addition, these blister groups are called mild, due to the R_{mtp} exceeding 55 m. Figure 3 shows the relationship between center blisters and 85th percentile speed. In Figure 3, when R_{mtp} value increases, speed of vehicles increases. Therefore, R_{mtp} should be decreased.

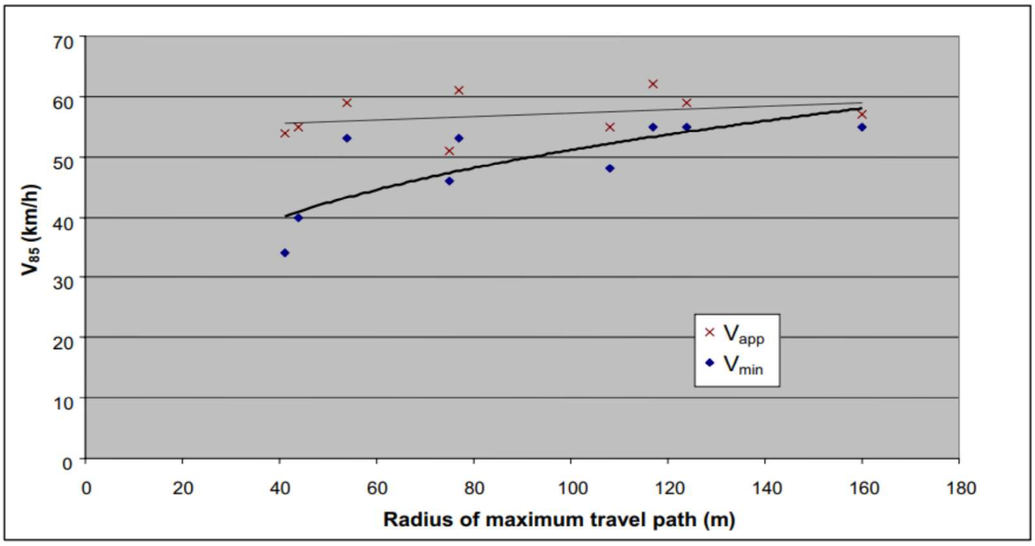

Figure 3: Relationship between the 85th percentile speed at mild center blisters, V_{min}, and R_{mtp} plus approach speed, V_{app} (Jurewicz, 2009)

Power regression equation at data points:

$$V_{min} = 14.75R_{mtp}^{0.27} \quad (2)$$

According to Jurewicz (2009), about 0.05, their relationship and coefficients give statistically logical results, also R^2 value was evaluated 0.6. In relation to this situation, Jurewicz (2009) announced that the standard error term was appraised as log(V_{min}) +/- 0.05, or +/- 6 km/h at forecasted V_{min} of 50 km/h. After that, impact of approach speed on speed decline was searched for center blisters, and some formulas was improved. Jurewicz (2009) performed a multi-linear regression to find the relationship between the V_{min}, V_{app}, and R_{mtp}.

$$V_{min} = 1.1V_{app} + 0.1R_{mtp} - 22.3 \quad (3)$$

where V_{min} and V_{app} is in km/h and R_{mtp} is in meters.

Jurewicz (2009) pointed that equation (3), the value of R^2 was calculated as 0.75 and the standard error turned out to be 4.3 km/h, and the relationship and coefficient turned out to be statistically significant at the 0.05 level. In Table 2, the situation of increase at the main road width and increase at the traffic volume at the same time is observed.

Table 2: Capacity of two-lane roads with different carriageway width (Chandra and Kumar, 2003)

Section	Carriageway width (m)	Total capacity (PCU/h)
I	8.8	3,590
II	7.4	3,002
III	6.9	2,656
IV	6.7	2,549
V	6.6	2,507
VI	6.4	2,290
VII	5.5	1,905
VIII	6.0	2,095
IX	8.0	3,220
X	7.0	2,707

Reducing lane width is one of the methods to reduce traffic speed. Thanks to the speed-volume relationship, the capacity of different two-lane sections can be understood with varying carriageway widths. In fact, Chandra and Kumar (2003) introduced that the speed-volume relationship can set the capacity of different two-lanes via changing the width of carriageway. The formula following the second curve relationship is:

$$PCU_1 = \left(\frac{V_c}{V_i}\right) / \left(\frac{A_c}{A_i}\right) \quad (4)$$

where V_c and V_i are equal to mean speeds for vehicles. Then, type i vehicles, separately, in the traffic stream; and A_c and A_i are equal to their respective reflected rectangular areas on the road. PCU means passenger car unit.

$$C = -2184 - 22.6w^2 + 857.4w \quad (5)$$

$$R^2 = 0.991 \quad (6)$$

where C= capacity of the road (PCU/h) and w= total width of the carriageway in meters.

According to Chandra and Kumar (2003), equation (5) can generate a capacity prediction for two-lane roads with a carriageway width varying between 5.5 and 8.8 meters. There is the right proportion between carriageway width and traffic volume, the situation is demonstrated in Figure 4.

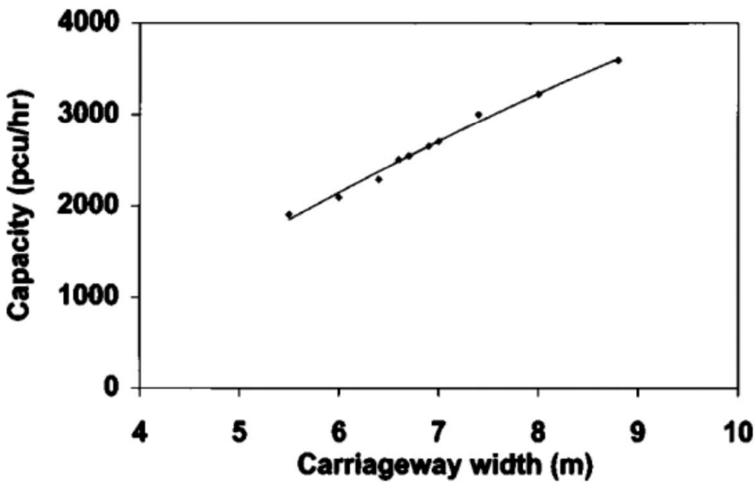

Figure 4: Capacity as related to total width of carriageway (Chandra and Kumar, 2003)

Additionally, for lane narrowing, some formulas were improved by Minnema (2006).

$$V = 26.71 + 0.1839L - 0.000239L^2 \quad (7)$$

where V is speed in the 85th percentile in km/h and L is length of straight residential street in meters. capacity of the road (PCU/h) and w= total width of the carriageway in meters.

Also, a lot of traffic calming applications are applied as slow points (chicanes), kerb extensions, impellor. Generally, slow points are set up in places where vehicle speeds are excessive and vehicle-pedestrian clashes are high. However, installation of slow points does not have formulas precisely as center blisters. Slow points do not have a clear standard design geometry. There are only specific design principles which are clearly presented in Table 3.

Table 3: Slow points installation rules and processes (Main Roads, 2020)

Procedure of slow points installation	
1)	The first slow point of a street must be within 100 meters of a sharp corner (or the end of the street) for preventing speed of vehicles which approach. Maximum speed of the vehicles cannot exceed 50 km/hr.
2)	The remaining lane width from the device (chicane) must be at least 3 meters.
3)	Generally, devices are designed as 5 meters long on single lane roads.
4)	Generally, on double-lane roads, the devices are designed to provide an island length of 10 meters (minimum).
5)	Deflection angles can vary from 10 to 30 degrees. (Depending on the required level of control)
6)	Frangible bollards with reflectors can be utilized to depict the shape of the gadget and to ensure landscaping. A Give Way sign can be used on one approach to establish the priority. Generally the sign is set on the lower traffic approach or the worst direction of sight distance.
7)	To protect four-wheel motor vehicles from being straddled at the median island, the width of it should be minimum 1.2m.
8)	Parking prohibitions are needed to ensure the carriageway through angled device keeps empty at any time. It is important to disable parking on both lanes of approach and departure. If the carriageway width is enough, protected parallel parking on the approach can be fine.
9)	Pedestrian movement around slow points should be prepared well, though landscaping can cause sight problems.
10)	The impact on adjacent driveways should be given importance and evaluated.

Slow points can act as a deterrent on traffic and, the discomfort experienced by residents can be reduced. Then, slow points provide shorter crossing distance for pedestrians (Main Roads, 2020). Although the cost of installing slow points is minimal, they have some disadvantages. For example, noise can be increased on traffic, and slow points can restrict ambulance passes, but cannot slow down motorcycles. Moreover, they may cause conflicts between opposing motorists incoming simultaneously at a single lane slow point. Finally, opportunity of parking vehicles can decrease. DOWL Engineers (2001) indicate that a traffic calming program can be responding to citizen requests for action or identifying issues and starting action ahead of accidents and many other undesirable costs Traffic calming practices can create wider region-wide improvements with multiple streets. Traffic calming application courses have 3 significant steps. They are project initiation, project selection, and plan development.

In the step of project initiation, projects should not be created on their own. Traffic calming projects should be created according to the common interest of the neighbourhoods through associations serving the peace of the society. Then, project selection is important for providing efficiency, and streets must be functionally classified for traffic calming. After that, plan development phase should be started. The project impact area should be determined by staying in touch with the public, which accepts traffic calming. The fact that there are more than 100 vehicles per day in any street in residential areas and an increase of more than 600 vpd (vehicle per day) in any collector street is defined as a significant impact. Furthermore, DOWL Engineers (2001) stated that the impact area is usually larger for measures of volume control than for the ones for speed. It is also larger for severe control measures for speed than for mild measures, such as speed humps and center island narrowing respectively. The volume effects of some commonly used traffic calmings are shown in Table 4 prepared by Institute of Transportation Engineers which are Alaskan. Speed reducing rate of some traffic calming devices is shown by Table 4.

Table 4: Volume effects of some widespread traffic calming measures (DOWL Engineers, 2001)

Measure	Decrease of Average Percent in Traffic Volume
Speed Humps	20%
Speed Tables	12%
Traffic Circles	5%
Narrowings	10%
Full Closures	44%
Half Closures	42%
Diagonal Diverters	35%

4. CASE STUDY AND DISCUSSION

Despite the advantages of center blisters, the center blisters have not been applied in Antalya yet anywise. However, the center blisters can improve traffic quality in Antalya emphatically. Then, owing to speed reducing feature of the center blisters, safety of pedestrians can increase. In Table 5, features of center blisters are demonstrated.

Table 5: Features of center blisters (Minnema, 2006)

Features of Center Blisters	Effects
Traffic Volumes	No change
Pedestrian safety	Increase
Crash Risks	No information (In literature)
Noise and Comfort	No information
Speeds	Reduces, 24% (Jurewicz, 2009)

According to this information, Minnema (2006) stated that regular evidences showing decrease in speeds can be fair enough to demonstrate the validity of center blisters. Although, there is no information relating to crash risks rate of center blisters in traffic in literature, Jurewicz (2009) determined that center blisters can decrease crash risks 18% in traffic in his researches. The aim of this case study is to show how to decrease the speed in some settlements to some extent effectively. In Table 6, speed limits of vehicles are demonstrated.

Table 6: Speed limits law for in Turkey, only for residential areas (KGM, 2019)

Vehicle type	In residential area (km/h)
Auto, Minibus, Bus, Van, Additional line, Panel van, Truck, Tow truck, Motorcycles	50

Center blisters should be installed for critic zones (as hospitals, schools, health clinics etc). In Antalya, in Korkuteli in front of Korkuteli District State Hospital and Korkuteli No. 3 Family Health Center (on Korkuteli-Tefenni road), center blisters application could be installed. Three Center blisters can be installed with 200 meters apart. Middle one should be installed just across the hospital for maximum efficiency. Also, others could be in front of and behind the middle. According to Table 6, V_{app} (approaching vehicle speed) could be defined 50 km/hr in residential areas. Transition of other vehicles (not in the Table 6) can be prohibited for a smooth traffic flow. After that, R_{mtp} (radius of maximum travel path) should be small as much as possible, because when R_{mtp} is smaller, speed can be reduced with high ratios. Consequently, Jurewicz (2009) discussed that center blisters can be a successful gadget for lessening speed when the radius of travel path is low. Therefore, R_{mtp} becomes 30 meters. According to these values, power regression becomes; $V_{min} = 36{,}9$ km/h according to equation (2). Then speed variation (ΔV) becomes $50 - 36{,}9 = 13{,}1$ km/h. After that, effect of approach speed on speed reduction becomes $V_{min} = 35.7$ km/h according to equation (3). In addition, V_{min} could be reduced with other traffic calming application (using simultaneously). Minnema (2006) pointed that center blisters could decrease 85th percentile speed 38%-44% (Table 1). According to speed reduction of center blisters project which is in Korkuteli-Tefenni road: $50 - 35.7 = 14.3$. Thus, the percent is found as 28.6%.

Instead of center blisters, slow points could be utilized effectively. However, as center blisters, for installation any formulation does not available for slow points. Slow points have some design considerations. In Figure 4, traffic volumes of Korkuteli-Tefenni road are shown, and processes for installation slow points are as follows:

1) Across the Cafe A, first slow point (chicane) can be put. The first slow point in a street should be set up 100 meters from the street entrance. Thus, the speed of the approaching vehicle might not surpass 50 km/h (Main Roads, 2020).
2) According to Ministry of Transport and Infrastructure General Directorate of Highways the traffic volume does not exceed 3000 vpd on Korkuteli-Tefenni road. Slow points should not be applied on roads where the traffic volume surpasses 3000 vpd (Main Roads, 2020).

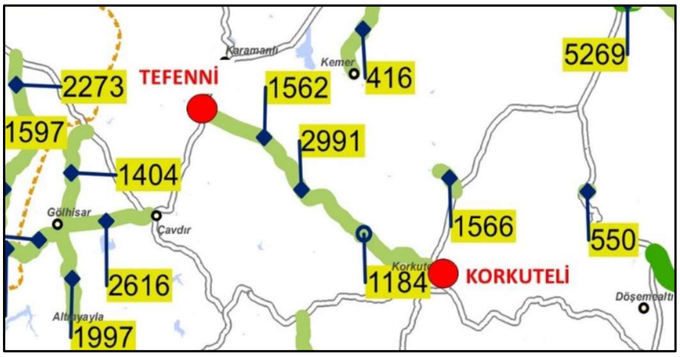

Figure 4: City Roads Map 2019, zoomed for Korkuteli-Tefenni road (KGM, 2019)

3) The minimum lane width remaining from the device must be at least 3 meters, however in this project, lane widths are 3.5 meters and device widths are utilized 4 meters approximately.
4) Minnema (2006) pointed that slope of way should be lower than 8% or equal.
5) Shape of devices becomes parabolic in this project.
6) The length of the devices to be installed on double lane roads will be 10 meters.
7) A warning sign will be placed 50 meters before the devices for demonstrating slow points. At the same time, D4-1-1A hazard marker could be utilized on the devices.

8) For four-wheel drive vehicles and trucks, the median island must be large sufficiently to dissuade being straddled. Then, the width should be 1.2 meters at least (Main Roads, 2020). So, 1.2 meters or 1.5 meters can be preferred.
9) Parking restriction can be applied to keep the main road always open.
10) Devices can be placed at 25-meters intervals. Thus, there will be room for maneuver for long and wide vehicles.
11) Between Cafe A and Food Market (850 meters) where locations of chicanes are shown in Figure 5, $10 + 25 = 35$ (every 35 m, one slow point should be installed), $850 / 35 = 24$ (chicane numbers for one road which has 2 lanes) and $24 * 2 = 48$ chicanes are enough for two roads.
12) Owing to slow points, Korkuteli State Hospital and No. 3 Family Health Center can be safer.
13) Bus routes must be changed, alternative roads can be utilized. (Also, for commercial vehicles this situation can be valid).
14) For removing obstruction of sight distance, trees on the highway should be cut.
15) At the end, speed of vehicles cannot exceed 40 km/hr in traffic owing to slow points devices.
16) Ambulance passes will be behind the hospital. Thus, they are not exposed to slow points.

Figure 5: Distance Between Cafe A and Food Market (Source: Google Maps)

Table 7: Features of slow points (Minnema, 2006)

Features of slow points	Effects
Traffic Volume	Average volumes reduce 15% at single lane slow points and 7% at two way slow points.
Pedestrian Safety	No effect
Crash Risk	Reduces 54%
Noise and Comfort	Information not available
Speed	Decreases

In Table 7, features of slow points are explained. Despite Table 7, because of slow points, noise can be increased but, discomfort to residents is minimal, and it provides ease of transition to pedestrians when it is used to narrow the highway (Main Roads, 2020). Minnema (2006) pointed that major proofs have been found for the effects of slow points on decreasing the vehicle speeds. Usually, single-lane slow points limit vehicles speed to 25 km/h and, two-lane slow points limit vehicles speed to 40 km/h (Main Roads, 2020).

5. CONCLUSION AND RECOMMENDATIONS

At the end, slowdown points and center blisters turn out to have different effects. Even if the decline of the speed of vehicles in traffic is formulated according to the radius of maximum travel path for center blisters, a special formula has not been developed for the slow points. However, traffic safety is very important in school districts and healthcare areas and traffic accidents should be effectively minimized (EGM, 2020). Already, 1.25 million people are killed every year in traffic accidents in the world (Cnn Türk, 2017). According to researches, central blisters can reduce traffic accident rates by 18%, while slow points reduce traffic accident rates by 54%. Therefore, installing slow points instead of center blisters will give a more effective result. Also, according to researches, central bubbles have no effect in reducing the traffic volume however; according to the researches, a definite conclusion was obtained that slow spots reduce the traffic volume, and slow points reduce traffic volume by 7% on single lane roads and 15% on double lane roads. Depending on these, establishing slow points is a more correct option.

The situation and movements of pedestrians, vehicles and animals on highways are called road traffic. In the last decades, the problem of traffic was added among the current problems of people in cities that became crowded in accordance with industrialization. Pedestrians and vehicles are two main elements of traffic on highways. Although it is often used to impose bumps to reduce vehicle speed in roads, horizontal speed calmings are also used to reduce the speed of the vehicle in traffic. Unfortunately, horizontal speed calmings are not widely used in Turkey. It is very important to find many problems that occur in traffic and find effective solutions. For example, where bumps are not enough, slow points can be installed. In addition, horizontal traffic calming systems can be developed or combined with other traffic calming elements for achieving more effective results. In addition, it is a good option to cover the deceleration points with a smooth rubber component to prevent damage to both vehicles and deceleration points in case of any rubbing or impacts. Such a design can be more permanent and longer lasting. Finally, since 1960s, horizontal speed cutters used in many countries such as in the Netherlands, Germany can also be used widely and effectively in Turkey and, problems experienced in traffic can be minimized.

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