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Analysis of the impacts of average speed enforcement on driving speed of university members in Turkey

Türkiye'de ortalama hız uygulamasının üniversite mensuplarının sürüş hızı üzerindeki etkilerinin analizi

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Abstract

In highly motorised countries around the world, average speed enforcement is a new and advanced technological approach that is growing in popularity. This paper investigates how a mobile average speed system affects speed on routes within the boundaries of a university campus. Firstly, the necessary system software and infrastructure were completed, and in the following 4-month period, before and after speed studies of the drivers were carried out. The first hidden (before) and the second announced (after) average speeds of drivers were measured on 11 different routes. The average speeds recorded in the before period were compared with the average speeds recorded in the after period. In this practice within the borders of the campus, only announcements and warnings were made to the drivers and no penalties were imposed. As a result, standard deviations decreased and average speeds decreased by 2.15 km/h (4.50 per cent), 1.81 km/h (5.10 per cent) and 4.50 km/h (8.35 per cent) on routes with 20, 30 and 50 km/h speed limits. 85% percentage speeds decreased by 4 km/h (6.50%), 3 km/h (6.70%), 3 km/h (4.70%). The rate of speed violations by drivers decreased from 69.38 per cent in the first period to 63.01 per cent in the second period. The proportion of vehicles obeying speed limits increased from 30.62 per cent in the first period to 36.99 per cent in the second period.

Keywords: Average speed enforcement, average speed, before/after period, independent sample t test

Öz

Dünya çapında son derece yüksek seviyede motorize olmuş ülkelerde, ortalama hız uygulaması popülerliği artan, yeni ve gelişmiş bir teknolojik yaklaşımdır. Bu makale, bir üniversite kampüsü sınırları içindeki güzergahlarda, mobil ortalama hız sisteminin hızı nasıl etkilediğini incelemektedir. İlk olarak gerekli sistem yazılımı ve altyapısı tamamlanmış, daha sonraki 4 aylık süreçte, sürücülerin önce ve sonra hız etütleri yapılmıştır. Sürücülerin 1.'si gizli (önce), 2.'si ise ilan edilmiş (sonra) ortalama hız değerleri 11 farklı güzergâhta yapılmıştır. Önce döneminde kaydedilen ortalama hızlar, sonra döneminde kaydedilen ortalama hızlarla kıyaslanmıştır. Kampüs sınırları içerisindeki bu uygulamada, sürücülere yalnızca duyurular ve uyarılar yapılmış, herhangi bir ceza uygulanma yapılmamıştır. Sonuç olarak, standart sapmalar düşmüş, ortalama hızlar 20, 30 ve 50 km/s hız limitli güzergâhlarda 2.15 km/s (%4.50), 1.81 km/s (%5.10) ve 4.50 km/s (%8.35) azalmıştır. 85 yüzdeli hızlar ise 4 km/s (%6.50), 3 km/s (%6.70), 3 km/s (%4.70) azalmıştır. Sürücülerin hız ihlali oranı önce döneminde %69.38 iken, sonra döneminde %63,01' e düşmüştür. Hız limitlerine uyan araçların oranı ise önce döneminde %30.62 iken sonra döneminde % 36.99'a yükselmiştir.

Anahtar kelimeler: *Ortalama hız uygulaması, ortalama hız, öncesi/sonrası periyodu, bağımsız örneklem t testi*

1 Introduction

Speed is a fundamental concept in traffic engineering and the most important factor that drivers take into account while choosing alternate routes or forms of transportation. Traffic speed is a factor that interests almost everyone [1]. Speed definitions that provide a net measurement are required when road transportation is taken into consideration from a research perspective on speed. The two types of speed data that are usually collected are spot speed and average speed. A vehicle's spot speed is the independent vehicle speed recorded while it is moving through a specific location on the road. Conversely, average speed describes the normal speed of the vehicle between two points that are separated by a given distance [2].

Driving faster than is reasonable under the circumstances, "including the weather, traffic, light, and road conditions," in addition to violating the official speed limit, is called speeding. [3]. High travel speeds shorten travel times, which improves mobility and the economy. A notable reduction in travel time supports the growth of the local and national economies. The rapid transportation of goods and services leads to advancements in many activities from education, trade to tourism in addition to increasing employment [1]. Nonetheless, speeding poses a serious threat to worldwide traffic safety on all kinds of roads. Speeding has the highest penalty as a traffic violation in Turkey [4]. According to findings from recent research conducted in Turkey, driver error-related incidents account for 90% of all accidents—a very high rate. Speeding accidents constitute approximately 40% of the total accidents [1],[5]. With greater speed comes an increased risk and severity of accidents [6].

Since speeding is one of the most important factors for deadly road accidents, majority of the road administrations enforce speed limits to obtain the proper operating speed [7]-[9]. Speed management is applied frequently in many countries for improving road safety. Enforcing suitable speed limits is one of the most crucial rules for achieving this goal [7]. Subject to various road classes, vehicle kinds, and residential features, speed restrictions are indicated by traffic regulation signs. These signs can also be used to enforce legal regulations.

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Overcoming legal speed limits is seen as a criminal violation in several countries [1].

Highway traffic safety is becoming increasingly significant on a global scale. To address the problem of traffic speeding, several nations employ a variety of speed enforcement techniques. Radar devices are the most widely used tool for police monitoring [10]. In Turkey, radar is typically employed to enforce speed limits on highways and urban roadways [11]. At radar control locations, spot speeds of cars are monitored, and drivers who exceed the speed limit are fined. If the driver knows in advance the location of the control point, they can avoid fines by slowing down as they approach the point and exiting it at a speed below the posted limit. Consequently, an increase in spot speed is only seen at or around the radar position. This enhancement is useless over large distances and is unable to reflect a specific route network. The new system's requirement for a large number of police officers, vehicles, money, and time is another disadvantage [12]–[14]. Motorists exhibit inconsistent speed behavior and they cannot be assessed equally and fairly by the police due to such enforcement methods which result in decreased police efficiency. However, rather than punishing drivers, the purpose of traffic laws is to reduce the number of fatalities and injuries brought on by traffic accidents and their aftermath. [14], [15]. A longer stretch of road can have continuous automated speed enforcement with average speed technology. While "average speed" applications can be utilized over longer road segments and hence have a greater impact on drivers, spot speed applications can be helpful in specific places where there has been a history of incidents. Because it targeted a sustainable speeding behavior, average speed enforcement may be significantly more popular with the public than previous enforcement tactics [16]–[29].

Programs that "encourage vehicle sharing, discounts for public transportation, and park fees for vehicles entering the campus, etc." are among the many that the university runs. However, vehicle use is not reduced as a result but is increased further and further. Additionally, since cars and pedestrians frequently use the same places, there is a higher chance of accidents involving pedestrians. Furthermore, by haphazardly crossing the roadway from any nearby location rather than from designated pedestrian crossings, pedestrians put themselves and other drivers' safety at risk. On top of all these problems, the high ratio of vehicles speeding inside the campus also attracts attention despite the traffic signs indicating speed limits of "20, 30 and 50 km/h". Hence, traffic problems inside the campus also increase parallel to the increase in both pedestrian and driver faults in the campus traffic. Speed bumps are utilized as a deterrent to speeding in places like Turkish university campuses, despite their many drawbacks. Speed bumps may damage certain parts of the vehicle, e.g. 'after' passing the speed bump, the vehicle accelerates in order to gain the speed it has lost and this results in not only unnecessary fuel consumption, but also environmental and noise pollution [30]. For the first time, an approach with fewer drawbacks that uses a "average speed" monitoring system is used in this study to address the issue of speeding on university campuses. With this method, mobile license reading cameras placed at suitable intervals along the same segment are used to determine the average speed values of the cars based on their times of passage and the known distances between cameras. As such, the objective of this study was to compare the differences in average speeds of motorists via 'before'-'after' speed analyses between two periods, the first of which was carried out in 'secret' whereas the second one was 'announced 'after which the effectiveness of the system at the end of enforcement period was evaluated. T-test method was used for evaluating the speed data with $p<0.05$ accepted as statistically significant.

Given that the majority of spot speed readings are viewed as "unfair," it is believed that this kind of method will be able to lessen the public's disapproval of the current mobile speed enforcement initiatives. In addition, a motorist would be uncertain as to whether they are passing by a spot speed camera or an average speed camera which measures the speed between two points and thus they would be encouraged to drive within the speed limits for a longer period [25]. In the past, this type of enforcement was restricted to motorway conditions; however, certain nations (such as the UK and Australia) have begun to deploy this system on urban highways as well. This was the first study in literature which made use of sections in a university campus. The investigation and assessment of the efficiency of mobile average speed enforcement are not well covered in the literature currently in publication. Moreover, a significant portion of the study reported in the literature is based on studies carried out by organizations dedicated to road safety (such as highway institutions, police departments, etc.) or by manufacturers of the equipment used to enforce the evaluated average speed limit, which is in responsibility of operating and maintaining the system. This study was conducted with assistance from the University Rectorate and Safety Directorate so as to support the impact of the enforcement on motorists. This study is significant because it establishes a baseline for installations of a similar nature and this mobile system is also unprecedented in Turkey. The ability to read license plates at any time and from any location has been possible since cameras have been added to mobile devices.

It is clear that more research is required to understand how these enforcement strategies affect the university road network when one considers the prior studies that have been done on the effects of similar enforcements on highways. The large numbers of students inside the university campus along with the size of the university campus have made walking and biking popular forms of transportation. On the other hand, interactions with motorized vehicle traffic could put bikers and pedestrians in danger. Plans and programs should be developed which focus on creating a safer environment in the campus for pedestrians, cyclists and drivers. The aim of the present study was to manage the speed limits enforced enforced inside the campus area for pedestrian, cyclist and driver safety via average speed enforcement strategy, identify the level of accordance with the speed limit in addition to presenting and discussing a management method for improving road safety.

2 Background

To learn more about the impacts of section safety measures, it is crucial to conduct thorough "before" and "after" studies [31]. Average speed enforcement aims to enforce speed limits since it facilitates average vehicle speed assessment and traffic enforcement [25]. The Netherlands was the first country in the world to test average speed cameras and to implement them completely in 1997. The Netherlands now has 11 permanent average speed enforcement locations [19],[25],[32]. To date, application of the enforcement method has remained limited with UK, Europe, Australia and New Zealand [25],[26],[32]-[35]. The system's ability to track average speeds across a length of road is one of its advantages. As a result, drivers obey the speed limit, which reduces the disparity in vehicle speeds. Reduced speed differentials lead to increased traffic capacity, more uniform traffic flow, and more reduced speed differentials. Because section control approximates traffic flow, it not only makes better use of the existing infrastructure but also lowers noise and pollution from traffic [6],[7],[17],[25],[32],[35]-[37].

Average speed enforcement necessitates the installation of two or more cameras spaced apart along a section (Figure 1). When cars enter the system through the first camera position, additional images and data from the subsequent camera locations are also collected, combined with the initial data, and their license plate, vehicle, and/or vehicle registration information are also obtained. Afterwards, Automatic Number Plate Recognition (ANPR) and Optical Character Recognition (OCR) technologies are then used to match vehicle registration information (Figure 2)(ANPR is a technology that uses OCR on images to read vehicle registration plates to create vehicle location data. OCR is the electronic or mechanical conversion of images of typed.) [17]-[20],[25],[28],[32],[38]-[43]. When the computed average vehicle speed exceeds the established legal speed limit for that stretch, images and violation data (time, date, speed, etc.) are uploaded over a communication network to a central processing unit. After that, verified offenses are given a violation notice, and non-violating vehicles' data is destroyed after a predetermined amount of time [19], [25], [40], [42], [43].

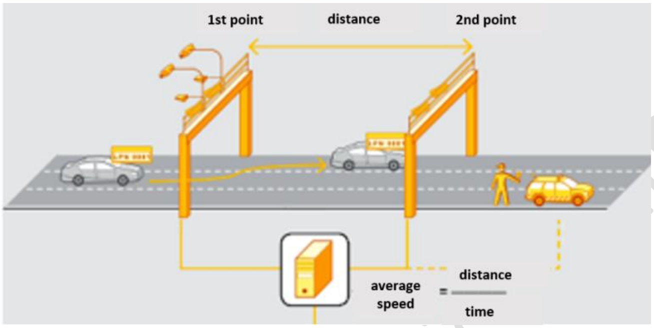

Figure 1. Average speed enforcement [44].

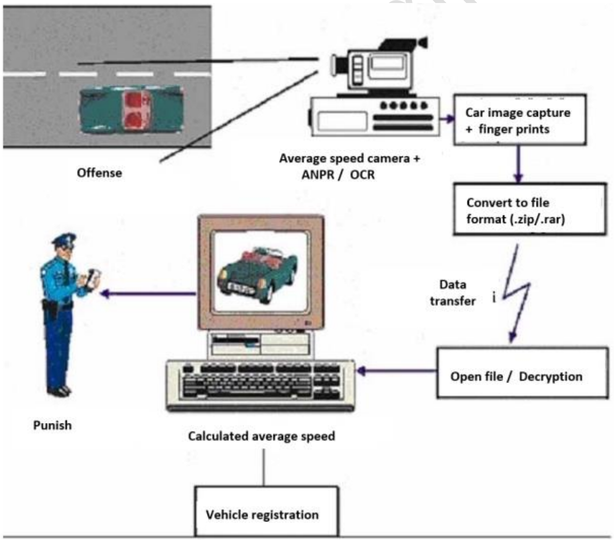

Figure 2. Average speed application [45].

Average speed enforcement has the benefit of tracking average speed over a predetermined distance, which promotes high speed limit adherence, a decrease in vehicle speed disparities, more uniform traffic flow, and increased traffic capacity. Cross section control ensures by the approximation of traffic flow better utilization of the existing traffic infrastructure as well as decreased emissions and noise pollution from traffic [7],[17],[25],[35]-[37]. The overall objective diagram, which is displayed in Figure 3, represents the outcomes obtained from applying average speed enforcement [6].

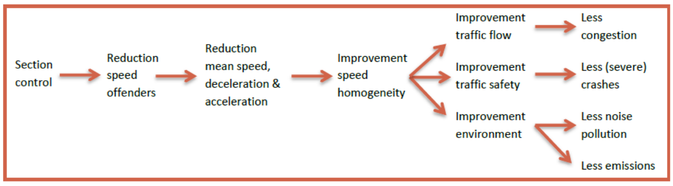

Figure 3. Average speed enforcement section control diagram [6]

2.1 Impact of the system on vehicle speed

Research assessing how average speed enforcement affects vehicle speed demonstrates that the implementation has a strong positive influence on a number of speed parameters. These parameters are "average speeds, 85 percentile speeds, ratio of speeding vehicles, and speed variation" [25].

Significant reductions in average and 85th percentile speeds were observed in the evaluations of average speed enforcement in literature [18]-[20],[25]. The first digital average speed camera system was set up in July 2000 on the M1's main connector road to Nottingham. Additional speed cameras were installed as part of a testing program in eight police zones. Two cameras were positioned along a 0.5 km stretch of road that was restricted to 40 mph. Following the enforcement, the 85th percentile and average speeds were both lowered to less than 40 mph [41]. Gil and Malenstein (2007) carried out studies in the Netherlands and Austria as well. These included the implementation of section controls in the Kaisermühlen Tunnel in Vienna and on the A13 highway between Rotterdam and The Hague, respectively. The results of both enforcement implementations put forth an average speed of 85 km/h for all vehicles for the ‘before’ period. This value was reduced to approx. 70 km/h only a short time after the implementation of the measure. Other speed measurements taken after a period of 6 months indicated that average speed over this section was balanced at 75 km/h. The reason for this is that, immediately "after" the enforcement rules are implemented, drivers have a tendency to follow them rigorously; however, over time, this inclination lessens as a result of inadvertent behavioral adaptations (also known as the "kangaroo effect") [19].

Numerous studies have demonstrated that average speed enforcement leads to noticeably better rates of speed limit observance. The reported violation rates were usually less than 1 percent, even in cases where the daily traffic numbers were high. Studies reported up to 90% of reductions in "the rates of vehicles exceeding speed limit" which indicates that this enforcement method is considerably effective especially in decreasing "overspeeding" behavior [8],[25],[46],[47]. An evaluation of compliance rates associated with the average speed enforcement system used on the Hume highway in Victoria State, Australia involved approx. 1,000 vehicles daily for speed violations (within a daily traffic volume of nearly 100,000 vehicles), and the violation rate was approx. 1-2% [25],[41].

In addition, “speed variance” decreased as well since the majority of motorists were travelling near the speed limit due to various average speed enforcement systems including permanent and temporary systems [17],[25],[28],[32],[42], [48],[49]. Three highway sections have been compared in the UK in these terms and the sections with average speed enforcement have been reported to have the lowest levels of speed variances [50]. Specifically, 60% of vehicles were observed to travel at a range of 15 mph on a 70 mph section where average speed enforcement was not in place. It was observed that 60% of the vehicles travelled at a range of 5 mph on the other 70 mph section where average speed enforcement was in place. Vehicles were observed to travel at a range of 3 mph on another 50 mph section where temporary average speed enforcement was in place. Indeed, typical speed profile of roads in the UK where this enforcement method is used shows that the majority of vehicles travel within a range of 3 mph of the indicated speed limit [25],[47].

Despite the inadequacy of studies which evaluate the effectiveness of an innovative system such as average speed enforcement in speed management, a literature review pointed at some findings suggesting that the enforcement method had a significantly favorable effect on accident rates and vehicle speeds [8],[18],[20] [21],[25],[26],[42],[51]. After examining the available data, it was concluded that average speed cameras produced more positive results in terms of section safety than other speed applications (such as fixed and mobile spot speed cameras) based on cameras. These behavioral changes were observed to be localized to the application area's vicinity and to be field-specific [52]. These studies put forth indications on the effectiveness of average speed enforcement method. Nevertheless, Soole et al. (2013) suggested the need for future studies in order to improve the scientific content of the evaluations carried out. There are currently few studies that have been published in peer-reviewed publications examining the relationship between average speed enforcement and traffic safety [35],[42]. Soole et al. put forth the necessity of the evaluation of mobile average speed cameras in order to increase their use and to determine their sufficiency as well as effectiveness. Because the implementation of such systems will increase application sufficiency with significantly low costs and in a more timely manner at areas with temporary section safety concerns (e.g. road construction sites with reduced speed limits) in comparison with permanent systems [42].

2.2 Impact of the system on accident rate

An approach should theoretically improve traffic safety because a lower average speed and speed variance reduce the likelihood of accidents [6]. Current studies have put forth that average speed enforcement decreased the number of all accident types significantly subject to decreases in vehicle speeds especially with regard to accidents involving mortalities and severe injuries. These findings, which encompass both permanent and temporary systems, are gathered from evaluation studies conducted in England, Italy, Austria, and the Netherlands. [19],[21],[25],[42],[51],[53],[54],[55]. More significantly, it has been suggested that the application is a very successful preventative measure for reducing speeding behavior. This bears important consequences with regard to section safety when the significant relationship between vehicle speed and accident risk is taken into consideration [8],[25],[56]. Only 0.5% of the vehicles in Holland have been found to have broken the speed limits since average speed enforcement was implemented on a portion of the A13 motorway. The total number of accidents was reduced by 47 % and there was a 25% decrease in mortalities and the number of losses [20],[36],[42]. Average speed enforcement resulted in a decrease of up to 65 % in accidents involving mortalities and injuries along with a decrease of up to 20 % in accidents with minor injuries across England [42],[57],[58].

2.3 Decrease in stop-start motion and improvement in traffic flow

An additional benefit related with average speed enforcement is, “a more homogeneous traffic flow and increased traffic” capacity. This benefit is due to the reduced vehicle speed variation along with the resulting increase in distances between vehicles [25],[32],[37],[59]. Decreased congestion resulting from a reduced speed variation due to improved traffic flow means that higher traffic volumes will be met on the section without any congestion in traffic flow [25],[32],[36], [37],[60]. Traffic flow improved especially during road works on Junction 28 in Ireland after average speed enforcement was set up resulting in a decrease of travel times from 10-15 minutes to 0-5 minutes during peak hours in the morning [59]. A before/after study was carried out recently in Italy which evaluated the impact of average speed enforcement on traffic flow images on a section of the A56 highway with recurring congestion. The results indicate that the vehicle speeds and accordingly traffic flow was more homogeneous and that the impacts of congestions decreased which led to more reliable and shorter travel times [7],[25].

2.4 Noise, fuel consumption and vehicle emissions

About 25% of the world's total emissions of carbon dioxide (CO_2) that are caused by human activity come from the road transportation sector. Therefore, substantial efforts are undertaken to reduce these emissions using a variety of strategies, such as enhanced vehicle technologies, traffic control, and altered driving habits [61]. According to relevant studies, the average application of speed enforcement may be related to the decrease in harmful vehicle emissions and traffic noise that results from improved traffic flow [25],[37],[61]. A study was carried out in the United Kingdom by Thornton (2010) in which the fuel consumption and emission of vehicles were compared for 70 mil/h and 50 mil/h highway sections monitored and not monitored by average speed enforcement. It was observed that the average speed enforcement application improved fuel consumption per vehicle by 4.87 mpg (mil/gallon) and 15.92 mpg for 70 mil/h and 50 mil/h speed limits respectively, that an annual decrease in CO_2 emission of 850 metric tons and 2.214 metric tons was attained along with reductions of 11.3% and 29.5% in fuel and emission. In addition, it was also observed that traffic noise and vibration also decreased [50].

2.5 Cost-Benefit analyses

The term benefit includes all positive financial impacts of a traffic enforcement application. Benefits related with section control when using average speed enforcement include decreases the number of accidents and traffic emissions at the related sections [62]. When compared with other speed application approaches, average speed enforcement is an expensive intervention [25]. It is difficult to estimate the cost of average speed enforcement application due to section restructuring and the technological changes involved. System costs are influenced by various factors, such as the quantity of cameras, their orientation (front, rear, or both sides), the number of lanes to be watched, traffic flow in a particular area (which influences processing and data storage requirements), and the use of overhead or pole-mounted infrastructure (urban, regional, or rural) [41]. In addition, it is possible to state that average speed enforcement is an expensive intervention with regard to operating and maintenance costs when compared with other speed enforcement applications [25],[42]. Highways Agency and Atkins Consultants (2009) prepared a report in which it was put forth that the average speed enforcement on Huntingdon-Cambridge A14 section in England has resulted in a decrease of 2.2 million £ in annual "accident cost" within a period of two years. The general yearly cost-benefit of the system is 4.3 million £, according to figures computed three years after it was implemented [42],[57],[58]. Cost-benefit for average speed enforcement has been studied again in the United Kingdom in relation with "fuel consumption and vehicle emissions" as a result of which it was determined that an annual carbon savings of 68,000 £ per mile corresponds to a cost-benefit ratio of 2.72 with an annual CO_2 decrease of 850 tons per mile for highways with a speed limit of 70 mil/h. Whereas it has been estimated for highways with a speed limit of 50 mil/h that a cost-benefit ratio of 7.08 may be attained [50]. Even though the number of cost-benefit analyses is very small, the results are promising and indicate that it is a positive investment decision with regard to social and economic savings [25].

2.6 Comparison of average/spot speed camera effect and driver behaviors

When comparing the behavior of drivers with respect to average speed cameras and spot speed, there are notable differences. Each type of camera has a distinct speed perception area, which influences the cameras' "area of influence." There are a limited number of studies in literature that compare the impacts of average speed enforcement with the effects of other approaches [25],[42]. When discussing the benefits of average speed technology, Keenan (2002) argued that spot speed measuring fixed cameras have field-specific effects. However, he added that even though the penalties for drivers' speeds imposed by average speed enforcement are only visible at the beginning and end of the section where the sanctions are in place, they also have an effect over longer distances. According to the study, a sizable portion of the drivers observed in the vicinity of the spot speed camera locations also altered their behavior near the cameras, hitting the brakes suddenly 50 meters in advance of the cameras and speeding up suddenly after passing them. The most unsettling aspect is that some accident numbers have gotten worse since spot speed cameras were installed. Average speed enforcement reduces the likelihood that drivers may brake abruptly when they notice a camera and accelerate quickly after crossing the camera field, as well as the associated risks [22],[24]-[26],[28],[63]. Driver behaviors have improved with increasing use of average speed enforcement. Contrary to spot speed cameras for which the drivers are constantly on the lookout for cameras, average speed cameras ensures that the drivers focus on their own driving regardless of the objects on the street. This in turn supports the fact that drivers have perceived a control area rather than determining average speed cameras and reacting accordingly [48],[49].

2.7 Average speed enforcement: drivers' general thoughts and perceptions

According to a driving survey conducted in the UK, 74% of drivers said they adhered to the application of average speed. On the other hand, 18% of participants said that when the average speed application is not in use, it motivates them to travel at the posted speed limit. In addition, 56% of the participants have a perception that the impacts of spot speed application on vehicle speed only take place in the vicinity of the camera [48]. It was reported in a telephone survey carried out with 315 drivers at the New South Wales district of Australia that the average speed application is supported by 63% of participants [64].

2.8 Legal Regulations and Penal Sanctions in Average Speed Applications

There is a series of issues other than technological characteristics including the many legal regulations that should be taken into consideration when average speed enforcement is being set up. Many judicial and competent authorities require the type approval and certification prior to the installation of average speed enforcement. Legal requirements vary among judicial zones and are dependent on technical issues such as the sensitivity and reliability of the equipment as well as legal issues such as driver definition. Average speed enforcement was first legalized in 2010 at the Victoria State of Australia under "Section Safety Law (1986) and section Safety (General) Arrangements (1999)". Victoria was the first judicial district in Australia where this technology was first put into effect which was followed more recently by New South Wales, Queensland and Southern Australia regions with applications such as full operation or trial [25]. Average speed applications in Turkey are carried out in accordance with Annex 16 of the Road Traffic Legislation (Law Numbered KTK-2918) within the scope of TEDES (traffic electronic inspection system) studies.

Safety camera programs worldwide are operated on a country basis by way of partnerships established by the related enforcers (e.g.; police, local highway authorities). Fining limits vary from country to country for average speed applications. Fines for Belgian highways are 50 Euros for violations of up to 10 km/h and 5 Euros is added to the fine for each km/h violation after the first 10 km/h. Drivers are subject to lawsuits in case the violations are 40 km/h or above and are charged with fines ranging between 55 Euros and 2750 Euros in addition to driving restrictions for durations that vary from 8 days to 5 years [35]. General Directorate of Security applies fines to the drivers in Turkey who violate the speed limits.

3 Method

In this study, the number plates of the vehicles in the 'before'-'after' periods were read by mobile average speed measurement cameras. The difference between the 'before' and 'after' period is that motorists were made aware of the enforcement during the 'after' period, whereas they were unaware of the enforcement during the 'before' period. This made it possible to compare average speed differences during the 'before' and 'after' periods and to determine whether the average speed values of motorists decreased during the 'after' period without any penal sanction. Since the analyses of average speeds in both periods were carried out not only at a few limited spots but over 11 sections, it was possible to determine the speeding behaviors of motorists depending on the area.

3.1 Pilot area and sections

The campus of Akdeniz University served as the experimental area. Despite the numerous traffic signals that indicate 20 mph, 30 mph, and 50 mph speed restrictions, there are still a lot of cases of speeding on campus. The same areas are commonly used by both the pedestrians and vehicles (Figure 4.) which leads to increased risk of 'pedestrian strike' accidents. Furthermore, 10 accidents have been recorded per year due to over speeding (Figure 5) [43],[65].

Figure 4. Vehicles and pedestrians in the same vicinity [65].

Figure 5. An accident in the campus [65].

The topic of whether the speed bumps now installed on university campus roads are effective enough is raised by the high number of accidents that occur there each year. In addition, university campuses are places where a specific set of drivers frequently enters and exits, as such creating the possibility of measuring the average speeds of the same vehicles many times. This is an important factor for it enables continuity for the obtained data in this study. Table 1 lists the dimensions of 11 road segments—including number of intersections, speed limit, length, lane width, number of lanes, number and diameter of horizontal curves, and number of speed bumps—that were subject to mobile average speed enforcement. In addition, Figure 6 provides representations of these areas on the campus map along with directions for traffic flow.

Figure 6. Average speed sections.

Table 1. Features of sections [66].

Section	Length (m)	Speed limit (km/h)	Number of lanes 1st point	Number of lanes 2nd point	Lane width (m) 1st point	Lane width (m) 2nd point	Number of intersections	Number of horizontal curves	Diameters of horizontal curves (m)	Number of speed bumps
A	908	30	2	1	3.50	3.50	4	2	288 / 108	3
B	717	30	2	2	3.50	3.50	3	-	-	3
C	890	50	2	2	3.50	3.50	1	-	-	1
D	890	50	2	2	3.50	3.50	2	-	-	1
E	425	30	2	2	3.50	3.50	2	-	-	2
F	600	20	2	2	3.00	3.00	-	-	-	-
G	600	20	2	2	3.00	3.00	-	-	-	-

H	615	30	1	2	3.50	3.50	3	3	40 / 30 / 106	1
I	594	30	2	1	3.50	3.50	3	3	106 / 30 / 40	-
J	695	30	2	1	3.50	3.50	2	2	30 / 22	-
K	695	30	1	2	3.50	3.50	2	2	22 / 30	-

The installed system consists of 2 units of passenger cars with section control attached on them, license recognition software, a laptop computer running the principal program, a high-speed internet provider for data transfer, and two section control cameras. At first, the cameras were installed within the trucks' trunks (Figure 7.). Trial measurements taken after installation revealed that the camera's height from the ground reduced the area of view available for reading license plates, producing results that were not technically satisfactory Moreover, it was believed that the system in the trunk would attract the interest of oncoming vehicles and people, endangering the privacy of the previously obtained measurements. As a result, it was thought that average speed data would not provide objective information.

Figure 7. Section Control Cameras, inside the trunk of vehicles [65].

Therefore cameras were installed in a camouflage inside a 'sound system luggage' mounted on 2 passenger vehicles in order to provide for the necessary license plate reading angle with the required ground clearance for license recognition cameras and to provide technically sufficient results in readings (for a high number plate capturing rate) (Figure 8). This was also to prevent pedestrians and motorists from recognizing the system (due to the covertness of measurements in the 'before' period). In addition, a sign reading 'noise measurement test' was placed on the windscreen of the passenger car to protect the covertness in the 'before' period and to prevent motorists from understanding that their average speeds were being measured (Figure 9.).

Figure 8. Average speed cameras setup placed on the vehicle (average speed camera&camouflage within luggage) [43],[65].

Figure 9. Noise measurement test writing (for diversion purposes) [43].

A wide-angle image that encompassed the full vehicle and its lane position was captured by the 2-lane number plate recognition cameras that were chosen. ANPR/OCR operating systems are integrates systems which do not require Personal Computer. This means that the cameras can analyze the license plates with no external device or software requirement other than 3G technology. They save more power and are suited to be used at distant regions as well, thereby providing advantages for the established mobile system. The license plate "scanning sensitivity" of ANPR/OCR systems is about 95%. Whereas the sensitivity of vehicle detection at various speeds is "spotting at speeds of 220 km/h" license plate recognition systems may analyze up to 75 plates per second [40]. The digital cameras used for license plate recognition have an IP function and a resolution of 5 MegaPixels at 75 frames per second. Cameras with higher resolutions have not been preferred for this purpose since their file sizes are larger, they are more costly and they require larger data processing systems. In addition, even though analog cameras have higher license recognition rates, the fact that digital cameras have specially developed operating systems and that they can carry out analyses without the requirement of any external device or industrial computer has made them more preferable [23],[67]. Cameras may recognize license plates regardless of the direction that the vehicles move in (coming or going). Forward looking cameras have been preferred since adverse weather conditions do not have any impact on their ability to recognize the license plates and since they enable driver recognition [23]. The system's software determined number plates of vehicles through a continuous video streaming method, since it is a mobile system it operates by transferring texts and images to the central central repository via a wireless link to the internet.

The system includes clocks which will provide the related date and time labels required for the captured images so that a basis for proof can be generated for the violations. The data and time adjustments of the system can be synchronized via SNTP protocol (Simple network time protocol (SNTP) is a protocol of the internet protocol family used to synchronize system time in networks.) [62]. The power supply that provides energy to the measuring license plate recognition hardware has been charged for 12 hours via 220 volt plug socket. The power supply that provides energy to the system could operate for only 5,5 hours even though it had to operate for 10 hours during the day. The energy system was changed completely due to this energy issue and a battery along with a battery charger were installed in place of the UPS system thereby reducing the charging time to 5 hours while increasing the duration for power supply use to 48 hours.

3.2 Data collection

Each mobile vehicle was parked at the appropriate location. Pairs were identified by geo-coding with a GPS device along 11 average speed sections in a way that does not interfere with traffic flow so as to enable the devices to read the whole lane(s) in the same direction. Cameras read license plates and identified average speeds on different average speed sections every weekday during a period of four months in total from parked and equipped vehicles. The days in this study were defined as weekdays from 08:00 to 18:00. Since the device was built on a university campus, there are no distinct traffic flow scenarios there. Driver speeds "from 10 km/h to 90 km/h" were included in the analysis, and the flow rate is 0–10 vehicles per lane (0–600 vehicles/hour). In addition, the non-inclusion of the weekend trips is due to the very low number of vehicles within the campus area during these periods (extremely light traffic flow conditions). This situation reduces the explanatory power of the approach as it cannot demonstrate the effectiveness of the enforcement.

Study periods were chosen within the spring term of the university. These periods appeared the most appropriate as there were no holidays and no roadwork within their duration. The speeding behaviors of motorists were analyzed in separate time periods, i.e. as ‘before’ and ’after’ periods. Vehicle license plates were read and average speed values were calculated during February and March 2013 in the ‘before’ period. To assess the efficacy of the findings, the study's "before" phase was conducted without the drivers' awareness at any point during the time. Not making it known to them in advance via university media ensured that the data obtained during the ‘before’ period scenario was unbiased and valuable for the purposes of this study. An announcement email was sent out to the related personnel and students containing information on the dates of the application of the system for the ‘after’ period at the end of the ‘before’ period, banners were placed on the entry gates to the campus and drivers entering through the university gates were given leaflets. Vehicle license plates were read after all these announcements and average speed values were calculated in the ‘after’ period (after announcement of the system) during April and May 2013. Since the sections were located within a university campus, 99% of the vehicles entering were light vehicles (less than 3.5 tons in weight). Therefore, the section analyses did not include heavy vehicles (weight >3.5 tons), and only small vehicles (passenger cars and light trucks) were included in the statistics computation.Data analysis

Speeds

Table 2. Number of vehicles at each measuring site that the study used [43],[66].

Section	Speed limit (km/h)	Section length	“before” Quantity of vehicles	“after” Quantity of vehicles
F	20	600	806	896
G	20	600	273	232
Total			1079	1128

The installed system's central server software can show the license plates of the cars that pass through the first and second license plate recognition points, as well as information about the date, time, average speed, and whether or not the average speed limit was exceeded. This data can also be recorded in Excel format. Using SAS (Statistical Analysis Software), the data were uploaded in Excel format after which various statistical analyses in line with the purposes of the study were carried out. The significance level of the study was identified as 0.05. Following that, a comparison was made between the average speeds observed during the "before" and "after" periods. An Independent Sample t-test was applied in order to determine the average speed variances of "all motorists" and "motorists who exceeded the speed limits" during the ‘before’ and ‘after’ periods for every section independently. In addition, minimum-maximum average speeds, standard deviations and 85th percentile speeds were calculated and cumulative speed distribution graphs were drawn.

Hypothesis test is useful tool for evaluating such safety measures, because it shows the trend of driving behavior changes, affecting driving behavior. Furthermore, in contrast with the majority of relevant studies, this analysis does not use a control area, in order to evaluate the speed enforcement. Since all of the campus's roads have average speed systems installed, no control area is necessary.

4 Results

In the "before" period, there were 23,060 cars with identified average speeds, while in the "after" period, there were 21,089 vehicles. Table 2. shows the sections and number of vehicles included in the study. In the pilot study conducted prior to the measurement, 11 routes were selected based on the following criteria: ‘routes with different speed limits, routes that are most preferred by drivers, routes where drivers are most likely to commit speed violations, routes where pedestrians on campus complain about speed violations’.

A	30	908	659	605
B	30	717	4962	6056
E	30	425	6203	4804
H	30	615	1123	766
I	30	594	539	526
J	30	695	2964	2134
K	30	695	412	295
Total			16862	15186
C	50	890	3820	3718
D	50	890	1299	1057
Total			5119	4775
Total			23060	21089

4.1 Average speed, minimum-maximum speed and standard deviation impacts

For the 11 routes that were part of the study, Table 3 displays the "speed limits, lengths, average speed measurements for the before and after periods, speed differences and speed variances". When compared to other sections in the "after" time, Section C, which had the highest speed of 54.27 km/h during the "before" era, had the largest speed decrease of 4.83 km/h (8.90%). Section I recorded the least amount of travel speed reduction, at 0.99 km/h (2.31%). Sections A and B showed increases in average speed values, with values of 0.35 and 0.17, respectively (an assessment of the significance of these speed gains can be found on the following pages). On the other hand, the average speeds in parts with 20, 30, and 50 km/h decreased to 2.15 km/h (4.50%), 1.81 km/h (5.10%), and 4.50 km/h (8.35%), respectively.

Table 4 shows "number of vehicles, average speeds, standard deviations, min./max. speeds" for the before/after periods for the 11 routes included in the study. In addition, according to the table, the normality assumption of the distribution of speed data was confirmed by Shapiro-Wilk and Anderson-Darling tests. An Independent Samples t-test as a parametric test was applied to determine whether the change observed in average speeds between the two periods was significant for 11 sections (Table 4.). Accordingly, there was an increase of 0.35 km/h in average speed during the 'after' period at section A, although the average speed during the 'before' and 'after' periods was below the 30 km/h speed limit. Furthermore, a 0.17 km/h increase in average speed at section B was also determined in the 'after' period. The quantitative gains were not statistically significant, according to an Independent Samples t-test, which also showed that the differences between sections A and B were not significant. Average speed was reduced by 4.83 km/h (8.90%) in section C and by 4.15 km/h (7.78%) in section D during the 'after' period. Average speeds in these sections were over 50 km/h during the 'before' period which were lower than the speed limit during the 'after' period. An Independent Samples t-test was carried out which also indicated that the differences in sections C and D were significant. Average speed was reduced by 2.23 km/h (6.70%) in section E during the 'after' period, by 1.79 km/h (4.00%) in section F, by 3.54 km/h (7.4%) in section G, by 1.12 km/h (3.00%) in section H, by 0.995 km/h (2.31%) in section I, by 2.69 km/h (6.00%) in section J and by 2 km/h (4.78%) in section K. Average speeds of these sections were over the 30 km/h speed limit during both periods. The differences across the portions were similarly significant, according to an Independent Samples t-test. In sections B, D, E, G, and K, respectively, the maximum average speed values dropped by 4 km/h, 9 km/h, 3 km/h, 6 km/h, and 16 km/h.

With varying speed limitations of 20, 30, and 50 km/h, Table 5 compares the speed variance between vehicles for the "before" and "after" periods for each of the sections. For each of the 11 routes, Table 5 displays "sections, speed limits, section lengths, before/after standard deviations, and standard deviation differences.". The highest standard deviation values during the 'before' period were 12.52, 11.32 and 10.74 in sections F, G and C respectively. These values were 12.34, 10.82 and 10.01 during the 'after' period again in sections F, G and C. Standard deviations in sections B, I, J, and D were observed to have increased during the 'after' period in comparison with the 'before' period. Speed variance between vehicles therefore did not decrease during the 'after' period in these sections. However, the standard deviation values in sections F, G, A, E, H, K, and C decreased during the 'after' period. Hence, there was less variance in average speeds during the 'after' period when compared with the 'before' period, i.e. speed variance between the vehicles decreased. Even though there was no speed differences between the two periods in section A, the fact that standard deviation decreased by 0.52 during the after period indicates a positive result with regard to the decrease of speed variance. The highest decreases in standard deviation were 0.73, 0.72, and 0.52 in sections C, E, and A respectively.

Table 3. Average speed statistics and speed decreases "before/after" [43],[66].

Section	Speed limit (km/h)	Length (m)	'before' average speed (km/h)	'after' average speed (km/h)	Speed difference (km/h)	Speed variance %
F	20	600	47.78	45.99	1.79	4.00
G	20	600	47.91	44.37	3.54	7.40
Total	20		47.81	45.66	2.15	4.50
A	30	908	28.16	28.51	-0.35	-1.24
B	30	717	31.64	31.81	-0.17	-0.54
E	30	425	33.37	31.14	2.23	6.70
H	30	615	37.24	36.12	1.12	3.00
I	30	594	42.81	41.82	0.99	2.31
J	30	695	45.01	42.32	2.69	6.00
K	30	695	41.81	39.81	2.00	4.78
Total	30		35.47	33.66	1.81	5.10
C	50	890	54.27	49.44	4.83	8.90
D	50	890	53.46	49.30	4.16	7.78
Total	50		53.87	49.37	4.50	8.35

Table 4. 'Before'/'after' average speed findings at sections and Independent Samples t-test.

Period	Section	Speed limit (km/h)	Number of vehicles	Average speed (km/h)	Standard deviation	Min. speed	Max. Speed	t	p
'before'	A	30	659	28.16	6.5319	10	44	-0.99	0.3234*
'after'			605	28.51	6.0123	10	48		
'before'	B	30	4962	31.64	7.0809	10	62	-1.24	0.2152*
'after'			6056	31.81	7.1536	10	58		
'before'	C	50	3820	54.27	10.7393	10	89	20.18	<.0001*
'after'			3718	49.44	10.0123	10	89		
'before'	D	50	1299	53.46	8.9694	12	89	10.72	<.0001*
'after'			1057	49.31	9.8241	10	80		
'before'	E	30	6203	33.37	8.4759	10	72	14.19	<.0001*
'after'			4804	31.14	7.7592	10	69		
'before'	F	20	806	47.78	12.5156	10	80	2.97	0.0030*
'after'			896	45.99	12.3430	10	86		
'before'	G	20	273	47.91	11.3226	10	86	3.57	0.0004*
'after'			232	44.37	10.8157	10	80		
'before'	H	30	1123	37.24	8.0535	10	59	3.03	0.0024*
'after'			766	36.12	7.5894	10	63		
'before'	I	30	539	42.81	7.6168	10	64	2.05	0.0404*
'after'			526	41.82	8.1129	11	68		
'before'	J	30	2964	45.01	7.1376	10	71	13.00	<.0001*

'after'			2134	42.32	7.4439	10	71		
'before'	K	30	412	41.81	6.8061	10	75	3.87	0.0001*
'after'			295	39.81	6.7611	18	59		

*Significant at the 5% level.

Table 5. Standard deviation data during the 'before'/'after' periods

Section	Speed limit (km/h)	Section length	'before' standard deviation	'after' standard deviation	Standard deviation difference
F	20	600	12.52	12.34	0.18
G	20	600	11.32	10.82	0.50
A	30	908	6.53	6.01	0.52
B	30	717	7.08	7.15	-0.07
E	30	425	8.48	7.76	0.72
H	30	615	8.05	7.59	0.46
I	30	594	7.62	8.11	-0.49
J	30	695	7.14	7.44	-0.30
K	30	695	6.81	6.76	0.05
C	50	890	10.74	10.01	0.73
D	50	890	8.97	9.82	-0.85

4.2 Cumulative speed distributions and 85th percentile speed impacts

Figure 10, Figure 11 and Figure 12. shows the cumulative speed distributions during the 'before' and 'after' periods in sections with speed limits of 50, 30 and 20 km/h. All three graphs presenting cumulative speeds over sections with three different speed limits clearly indicate the line shifting left during the 'after' period which is an indication that average speeds during the 'after' period were lower than those during the 'before' period. In addition, 85th percentile speeds, which were observed under the same conditions, are also seen within the distribution, which consists of speed values corresponding to an 85% zone 'after' vehicle speeds are sorted in an ascending order. However, these results show that 85th percentile vehicle speeds are above the posted speed limits for all periods.

The most widely used speed measure for operating conditions is the 85th percentile speed of the distribution of measured speeds under free flowing conditions. The goal of setting a speed restriction that is reasonably near to the 85th percentile speed is to accommodate as many vehicles that are traveling at or below the speed limit as possible [9],[28],[68]. In the present study, 85th percentile speeds were 60, 45, and 64 km/h in road sections with 50, 30, and 20 km/h speed limits respectively during the 'before' period, i.e. 'before' the announcement concerning speed limits was made. These results therefore indicate that motorists perceived the announced speed limits as inconsistent and many considered that these limits could be disregarded. Even though the 85th percentile speeds were still above the speed limits during the 'after' period, 85th percentile speeds were reduced by 4 km/h (6.50%), 3 km/h (6.70%), and 3 km/h (4.70%) respectively during this period in sections with speed limits of 20 km/h, 30 km/h, and 50 km/h,. It can be assumed as a result of the study that the sense of speed limit created by the physical conditions of the road was effective in both periods.

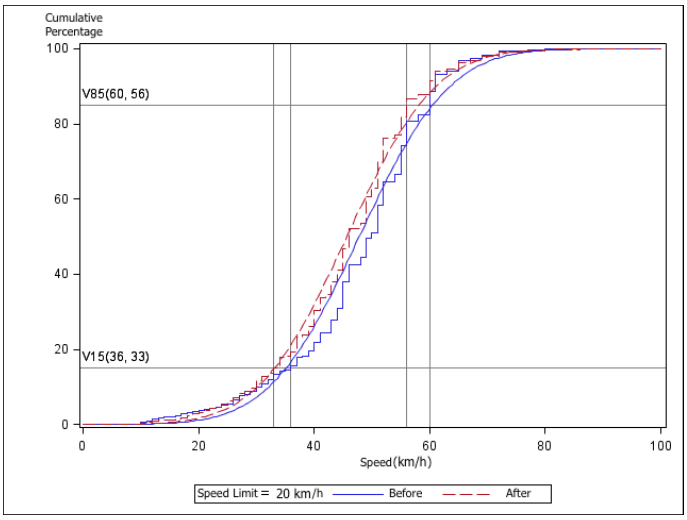

Figure 10. 'before'/'after' cumulative speed distribution and 85th percentile speeds (sections with 20 km/h speed limit).

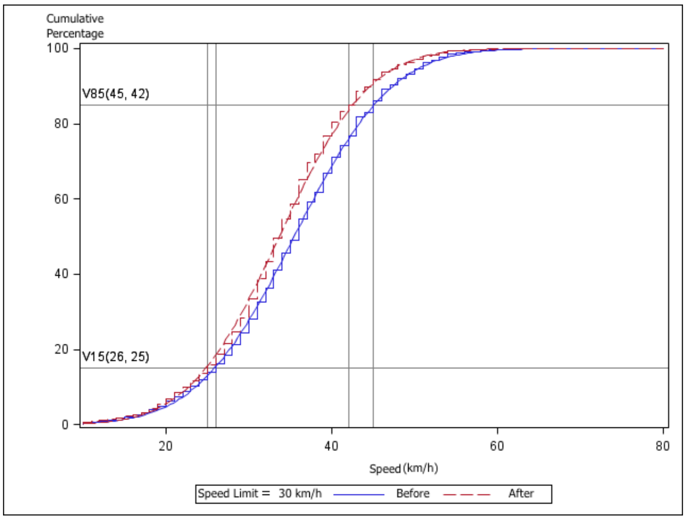

Figure 11. 'before'/'after' cumulative speed distribution and 85th percentile speeds (sections with 30 km/h speed limit).

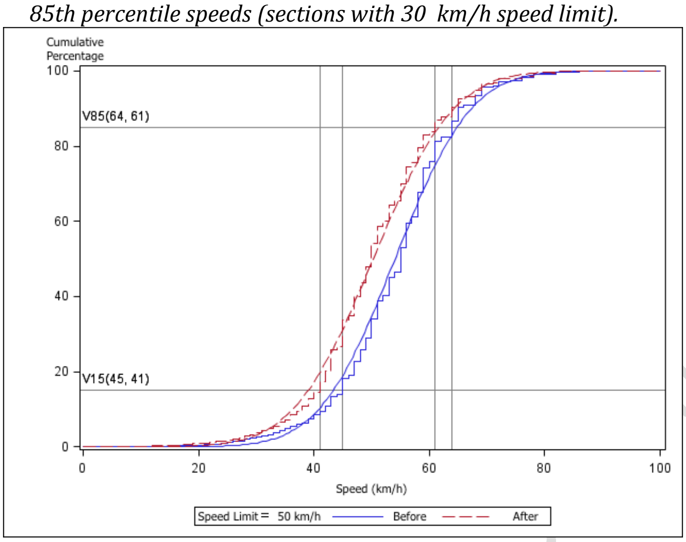

Figure 12. 'before'/'after' cumulative speed distribution and 85th percentile speeds (sections with 50 km/h speed limit).

4.3 Comparison of average speed data from before and after in relation to speed limit infractions

The following were the results of 'before'/'after' mobile system measurements deployed on 11 distinct sections based on the status of the violations: During the "before" period, 69.38% of cars in all parts were exceeding the speed limit; during the "after" period, this percentage dropped to 63.01%. Nonetheless, during the "before" period, 30.62% of the cars complied with the speed regulations; but, during the "after" period, that number rose to 36.99%.

The results of speed limit violations that happened "before" and "after" the mobile average speed system was put into place on 11 different sections are shown in Table 6. Given these results, an Independent Samples t-test was performed to see whether the system's announcement had any effect on the average speeds of drivers who broke the law in each section (A, B, C, D, E, F, G, H, I, J, and K). Average speeds of violating motorists decreased by 0.035 km/h and 0.68 km/h, and increased by 0.11 km/h in sections A, I, and B respectively during the 'after' period. An Independent Samples t-test put forth that the differences in sections A, I, and B were not significant. There were reductions of 1.87 km/h, 0.74 km/h, 1.65 km/h, 1.99 km/h, 4.02 km/h, 0.95 km/h, 2.32 km/h, and 1.43 km/h respectively in sections C, D E, F, G, H, J, and K. The differences in these parts were shown to be significant by an independent Samples t-test.

Table 6. Average speed t-test concerning 'before'/'after' periods for violating motorists.

Period	Section	Speed limit (km/h)	Number of vehicles	Average speed (km/h)	Standard deviation	t	p
'before'	A	30	257	33.91	2.6108	0.14	0.8901*
'after'			225	33.88	2.9418		
'before'	B	30	3051	35.95	4.1502	-1.03	0.3041*
'after'			3792	36.06	4.1953		
'before'	C	50	2552	60.00	6.7342	9.03	<.0001*
'after'			1608	58.13	6.1506		
'before'	D	50	827	58.57	5.9303	2.24	0.0256*
'after'			466	57.83	5.3143		
'before'	E	30	4087	38.23	5.3328	13.11	<.0001*
'after'			2719	36.58	4.6974		
'before'	F	20	777	49.00	10.9882	3.63	0.0003*
'after'			866	47.01	11.2409		
'before'	G	20	262	49.38	8.9189	4.84	<.0001*
'after'			225	45.36	9.3822		
'before'	H	30	953	39.75	5.2332	3.49	0.0005*
'after'			618	38.80	5.2536		

'before'	I	30	515	43.73	6.2434	1.68	0.0940*
'after'			492	43.05	6.6545		
'before'	J	30	2878	45.70	5.8850	13.41	<.0001*
'after'			2013	43.38	6.0881		
'before'	K	30	393	42.64	5.7292	3.18	0.0015*
'after'			265	41.21	5.5246		

*Significant at the 5% level.

5 Conclusions

Commuter drivers, those who drive on and off school all the time, are prevalent in areas like university campuses. As a result, it is feasible to test the same vehicles' average speed again. The drivers included in the present study represent the group of individuals that are part of the "administrative personnel, academic personnel, university students and other (those working at businesses such as the campus coffee etc.)". Average speed limit systems were implemented with no driver enforcement within the campus boundaries. The before-and-after data showed that the mobile system, which was installed at 11 separate locations with speed limits of "50, 30 and 20 km/h," was successful in getting the cars to slow down. The following violations were found for the same drivers: in the before period, 69.38% of the vehicles at all sections exceeded the speed limit; in the after period, this ratio dropped to 63.11%. While the percentage of vehicles that do not violate the speed limit increased from 30.62 % in the before period to 36.99 % in the after period. Numerous studies have shown that average speed enforcement is highly successful in enforcing speed limits compliance. It has been demonstrated that even in situations with large daily traffic volumes, infraction rates were typically less than 1% [8],[25]. When analyzing the compliance ratios associated with the OHTS application that was put into place on the Hume Highway in the Australian state of Victoria, it was stated that approximately 1000 vehicles (out of a daily traffic volume of up to 100,000 vehicles) are processed for speed violations each day, translating to a violation ratio of roughly 1-2% [25],[41]. It can be observed when the results of this study are compared with the results of other studies related with "speed violation" behavior that there is a serious requirement for enforcements in speed violation cases. With this method, drivers on campus have the chance to alter their habits before they commit an infraction that could result in a speeding fine. Rather than apprehending the offenders, the goal is to deter speeding behavior. [27],[39],[48].

The average speeds were above the speed limit in both periods in this study despite the fact that the average speeds decreased in sections F and G with a 20 km/h speed limit 'after' the announcement was made. As can be seen in Table 1, these two portions lack intersections, speed bumps, and horizontal curves. Hence, speed reductions are due to the geometric characteristics of the section (horizontal curve effect) as well as the turning and joining vehicles (intersection effect). Thus, speed limitation is due to a control other than average speed control (speed bump effect). As a result, despite the fact that average speeds decreased during the "after" period, these portions' geometric and physical features are thought to have contributed to low levels of compliance with speed limits during both times. Furthermore, it is a given that drivers find certain portions' speed restrictions to be inappropriate, necessitating the necessity for an ideal speed limit control [25],[36],[37],[60]. The low compliance ratios to average speed enforcement in sections F and G with comparatively lover speed limits may lead to opinions that the average speed enforcement has made no impact with regard to increasing safety. But in the early years of this enforcement's application worldwide, standard cameras lacked type certification for enforcing speed restrictions under 30 mil/h, which posed a barrier to lowering speed limits and growing the 20 mil/h network Sharp curves and speed bumps were employed for this reason. Even so, despite their effectiveness, these speed control methods are not well received by the public, raise emissions, and pose a hazard to emergency and service vehicles. There has been a shift in the testing of this system's application in low-speed urban regions (20 mil/h parts, for example).Research suggests that speed control devices, such as speed bumps, are not as effective as they formerly were. These devices can be costly, raise emissions, and create needless impediments for emergency vehicles [20],[69],[70]. It is reported that there are many current or pending plans for testing this approach in many different judicial areas. In the meantime, average speed enforcement has stirred up discussions with regard to its use in urban roads and especially the sections

of the road with lower speed limits. Researchers from both New South Wales and Australia Capital Region approve of the potential implementation of average speed cameras in urban environments. Criteria requirements in selecting the implementation locations have attracted significant attention. While accident histories and speed profiles have been approved as typical criteria to be used, it has been observed that the implementation practices are determined based on the local and political conditions in each judicial zone [25]. Hence, it seems obligatory to place cameras to ensure the automated monitoring of all violations in order to improve the effectiveness of the system at low speed limit university sections and to punish the violators in order to instill an actual feeling of getting caught/receiving punishment.

An increase of 0.35 km/h in average speedways observed in section A with a 30 km/h speed limit, although average speed was below the average speed limit in both periods. This could be explained as follows: four minor intersections are seen in section A in Table 1, it is therefore assumed that the vehicles with average speeds measured by the cameras had to slow down to allow other vehicles in front of them to maneuver and turn at the intersections. Furthermore, two curbs and two speed bumps located in this section are considered to contribute to the decrease in speeds during both periods. Since this part is so close to faculty buildings, it also includes pedestrian crossings that fall under the definition of a "pedestrian priority section." It is suggested that the reason for travel speeds being so close to the speed limits could be due to all these geometric, physical and enforcement-related characteristics. Decreases in average speeds in sections with 30 km/h speed limit were found in sections I, H, K, J, and E in an ascending order with section E having the highest decrease. It is assumed that the greater number (3) of minor intersections located in sections I and H resulted in less decrease in average speeds in comparison with other sections. Furthermore, the minimum level of pedestrian traffic in these sections indicates that speeding behavior is adopted and accepted by motorists in these sections. It is assumed that the sense of speed limit created by the physical conditions of each of the road sections played a role during both periods. It can be observed when these findings are taken into consideration that drivers display behaviors of "speeding slightly above the speed limit" at some sections with a speed limit of 30 km/h. The speeding behavior of drivers is socially accepted by the public especially when the violation is slightly above the speed limit [42],[71],[72]. However, it has been discussed in relation with speeding behavior at speeds that are slightly above the speed limit that it is a justification for speeding behavior and that imposing sanctions for speeding violations slightly above the speed limit is required even if at small levels. It has been observed that even slight violations of the speed limit are related with significant increases in risk of accidents and severe injury and that even small decreases in vehicle speeds may lead to significant reductions in accident outcomes [25],[56],[73]. Hence, it is an important road safety objective to reduce speeding at low levels. In this scope, it is of vital importance from a political perspective to explain to a critical public and media that "speed enforcement practices aim to provide improved road safety rather than acquiring minor and insignificant revenue from traffic violations". This problem has been emphasized as a significant difficulty in the recently published National Road Safety Strategy 2011-2020 of Australia [21].

At sections C and D, where there is a 50 km/h speed limit, the average speed was over the limit during the before period. However, during the after period, it was below the limit, and statistical analysis have shown that these decreases are statistically significant. This can be due to the fact that drivers have a tendency to strictly obey the regulations in these sections following the implementations. Based on these results, it can be considered that the speed limits enforced on these sections have been accepted by the drivers.

It is common knowledge that speed plays a critical role in maintaining road safety. The goal of many of the safety measures put in place is to make sure that drivers slow down and follow the posted speed limits. It is commonly known that the "change in average speed" has an impact on road safety in terms of the quantity of collisions, injuries, and fatalities. Nevertheless, the standard deviation of speed, the 85th percentile speed, the kind of speed distribution, and average speed are all impacted by traffic safety measures. [74]. A series of studies conducted at England, Scotland, Holland, Italy and France have provided proof that the standard deviation decreases in vehicle speed changes have led to improved traffic flow [16]-[18],[28], [36],[39],[47],[53],[62],[75]. Cumulative speeds at sections with three different speed limits have decreased during the after period in this study which can be considered as a positive outcome. In addition, while the standard deviation values during the before period were comparatively higher than other sections at sections F and G with speed limits of 20 km/h where highest speed violations took place during the before period, they were reduced very slightly during the after period (it was again much higher during the after period compared with other sections). Based on these results, it was considered that traffic flow has not improved as a result of the standard deviations in vehicle speed variability during the before/after periods at sections with speed limit of 20 km/h. Whereas the standard deviations at sections A, E, H, K, C decreased during the after period indicating that the speed variability among the vehicles was reduced due to less variance in average speed resulting in improved traffic flow. Moreover, it is indicated as a positive outcome of the present study that both average speed and standard deviations decreased during the after period at sections E, H, K, C as mentioned above.

The "85th percentile speed" concept has been used by road engineers for the past twenty years. The 85th percentile speed is the speed at or below which 85 percent of the drivers drive on a given road [2]. Previous studies have emphasized the benefits of road safety measures related with reducing the absolute velocities of the vehicles [76]. Whereas average speed enforcement assessments have typically recorded decreases in average and 85th percentile speeds. Moreover, decreases have been observed to a level at or below the speed limit at average and most frequently 85th percentile speeds. These consequences have been documented in relation to both temporary and permanent systems that have been put in place in a number of different nations worldwide[17],[19],[20],[25]. Despite reductions in the 85th percentile, speeds were observed in the 'after' period and these were identified to be above the speed limit in both periods. This suggests that motorists do not perceive the announced speed limits as reasonable and also that the sense of speed limit created by the physical conditions of the road had an effect during both periods. It is suggested that the speed distribution is adapted to travel speeds such as 85th percentile speeds as well as the geometry of the section, development type and roadside level of the section in order to make speed limits in these sections more reasonable with regard to the perspective of motorists and to prevent the limits from being disregarded so commonly [9],[28],[63],[68],[77]. USLIMITS2, a speed limit decision support software used in the USA is an expertise system based on the "speed preferences of the drivers".. The most commonly utilized operating speed criterion is the 85th percentile speed of the observed speeds under free flow conditions. Free flow speeds are those that are seen by cars that are not constrained by other moving cars or traffic control equipment. USA Manual on Uniform Traffic Control Devices suggests the adjustment of the speed limits to be close to the 85th percentile speed of the freely flowing traffic. The basis of adjusting the speed limit close to the 85th percentile limit is the inclusion of as much people as possible who are traveling at or below the speed limit [28],[68].

6 Discussion

Average speeds, 85th percentile speeds, percentage of vehicles violating the speed limits and the speed difference between vehicles all decreased as a result of this study. There is however an issue which should not be neglected despite these positive results. Speed and behavior of non-compliance with speed limits showed an increase over time in certain road sections. A higher compliance rate may be obtained via better communication and information strategy focused on section users as well as enforcement practice on violation proceedings. None of the speed implementation systems can be effective with an inadequate level of enforcement or without an enforcement strategy including penalties. "The system's speed limit management strategy" is one of the crucial characteristics enabling successful implementation of an average speed system (it is provided across the world by highway agencies and the police who deal with violations directly). A coherent strategy should be specified to change the behaviors of motorists towards a higher level of rapport with speed limits by way of sharing both speed data and information regarding implementation of enforcement [63].

There is proof that an optimal speed limit application is required in order to attain an improved traffic flow with the average speed application. As an example, a speed limit decreased from 100 km/h to 80 km/h accompanied an installation of the OHTS application in Holland. This decrease actually increased traffic congestions and partially neutralized the benefits on traffic noise and emissions [25],[36],[37],[60]. In this study, speed averages were above the speed limit in both periods at all sections with a speed limit of 20 km/h and some sections with speed limits of 30 km/h. In case speed enforcement is applied on these sections, increasing travel durations due to low speed limits may result in higher traffic flow especially at peak hours thus increasing congestion. Unrealistic speed restrictions may be disregarded by most drivers, but respect for speed limits can be increased by setting limits that are appropriate for the road's environmental context and driver expectations [14],[28],[78].

The "before-after" analysis is a suitable method to evaluate these kinds of enforcement actions. The hypothesis testing can yield important information on the variations in speed before and after enforcement, as well as reliable conclusions about the underlying mechanism influencing driving behavior as a result of speed enforcement. It is imperative that the university administration regulates this practice as a legal enforcement in order for this technique to yield meaningful insights on the "long-term" effects of such enforcement.

“Motorized vehicle-pedestrian-bicyclist” accidents are important public health issues especially in areas such as campuses. Campuses, with their large spaces and dense student body, offer a wealth of resources and opportunities, but they also pose special challenges when it comes to addressing concerns related to the safety of pedestrians and bicyclists. The Mediterranean University campus holds more than 65 000 pupils and faculty members. This large and defenseless population moves together with motorized vehicles every day in fast flowing traffic. Since a significant number of pedestrians and bicyclists are under risk, there may be an increase in the number of pedestrian and bicyclist accidents. Despite the fact that setting a speed limit may make cars drive slower and hence the risks of accidents at such campuses, they will lose their effectiveness over time if they are not managed efficiently and not backed up with proper investments [79].

Publishing articles on the results of such analyses with regard to improving traffic safety at other locations of the university may further emphasize the motivation of the present study. Enhancing the scientific rigor of past assessments need to be the aim of future investigations.

It is critical that drivers comprehend the technologies at their disposal since doing so will enhance their perspective and behavior as drivers. To educate and increase awareness among drivers about the need of implementing average speed restrictions and enforcement strategies, informational and awareness-raising campaigns should be run using a variety of media, including newspapers, radio, television, and social media. In addition, similar situations can be monitored on a different scale in turkey and comparisons can be made between the behaviour of drivers in different cities regarding the average speed practice.

7 Contribution by the author statement

Author 1 worked on the study's design, literature review, analysis and evaluation of the outcomes, and results review. Author 2 was involved in idea generation, material acquisition, results review, spell checking, and article content control.

8 Conflict of interest disclosure and ethics committee approval

The prepared essay does not require approval from an ethics committee. No one or any organization in this case has a conflict of interest.

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