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# Case study of low speed limit regions inspected by average speed enforcement: Opinions on speed limit enforcement of commuter drivers in Turkey

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**Abstract.** This paper provides information on the average speed enforcement system technology used in a university campus on sections with speed limits which is believed to be effective in moderating the speeding behavior of drivers in a certain period of time. To this end, driver characteristics and their opinions are given. In the final stage of this application, drivers are surveyed within the scope of "driver's personal characteristics, driver behaviors known by themselves, opinions on the average speed enforcement in the campus, and the speed limits as well as other enforcements". A sample group of 729 drivers who regularly enter or exit the campus are included in this study as a result of which 52.8% of the participants pointed out that the speed limit enforced by average speed enforcement was low. It is thought that drivers do not find the speed limits reasonable and that these limits may be neglected frequently in the future. Of note, the study area is a campus where speed limits are adjusted in terms of drivers' respect for these limits. These speed limits should be set such that they pose no risks to pedestrian/cyclist safety.



## 1. Introduction

Even though speeding is known to be a behavior with high risk, it is a commonly observed behavior thought by many drivers to be normal and socially acceptable [1–3]. Speeding culture is so imbedded that exceeding the speed limit is generally perceived as normal. Indeed, there is evidence that majority of the drivers consider speeding as the least serious traffic offence [4]. Eboli et al. [5] maintained that speeding could be pliable to many factors on specific road sections. Driving speed depends on the personal preferences, psychophysical states, and social pressure of drivers as well as the vehicle characteristics. It is also dependent on all types of interactions among the aforementioned variables as well as environmental factors such as weather conditions and road characteristics.

Speed enforcement is applied widely in many countries in order to improve road safety. Imposing the most suitable speed limits is the most fundamental method among such policies [6]. Speed limits are indicated by traffic regulatory signs which can be enforced by legal regulations or road signs. Driving at speeds higher than the legally allowed values is considered a traffic offence in many countries [3,7,8]. However, managing speeds using this strategy is subject to shortcomings; weak adaptation to speed limit may obviate the efforts for promoting safety. Thus, new speed enforcement methods are applied more frequently in many European countries in order to increase effectiveness. In this regard, average speed

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**Figure 1.** Pedestrians and vehicles in the same area.

enforcement measures the average cruising speed of all vehicles passing a section, thus ensuring that drivers obey the speed enforcement along the whole section. Such systems ensure the monitoring of all violations in an automated manner, thereby securing a precise, cost-efficient and just application in countries where the vehicle owner is directly responsible [3,6,9]. It is known that speed is of vital importance for road safety. Majority of the implemented safety measures aim to ensure that road users reduce their speeds and comply with the speed limits. The impacts of the "change in average speed" on road safety are well associated with the number of accidents and number of injured and dead individuals. However, traffic safety measures affect not only average speed but also 85th percentile speed, standard deviation of speed, and speed distribution, as well [10].

Areas such as university campuses are the places where a certain group of drivers regularly enter and exit the premises. There is a tendency to drive excessively fast at the Akdeniz University campus despite the traffic signs indicating speed limits of "20, 30, and 50 km/h". This poses a significant problem that should be overcome since about 10 recorded accidents occur annually due to speeding. Studies were carried out for a period of two months as a result of which it was determined that the "ratio of drivers with over speeding behavior" was 45.67% on sections with a speed limit of 20 km/h. However, the ratio for sections with speed limits of 30 km/h and 50 km/h was observed to be was 17.48% and 4.36%, respectively. Of note, drivers are defined as "over speeding drivers" according to the speed regulations in Turkey when they exceed the speed limits by over 30% [11]. The current speed bumps placed along the campus routes as traffic enforcement measures are not enough and there are certain known disadvantages to speed bumps (e.g., speed bumps may damage some parts of the vehicle while causing fuel consumption as well as environment and noise pollution). Moreover, the system was used on five weekdays on 11 sections with different traffic flows for examining the traffic conditions during campus entry and exit times in the morning (between 8:00–09:30) and in the afternoon (during 16:30–18:00).

Methods such as "encouraging vehicle sharing, providing discounts and free passes for public transportation, providing means for bicycle use in order to ease transportation and collecting a small amount of parking fee from vehicles that enter the campus, etc." have not been applied. Pedestrians and vehicles mostly use the same areas (Figure 1) which creates a risk of 'pedestrian strike' accidents. In addition, pedestrians put themselves and the vehicle drivers at risk by crossing the street where there are no pedestrian crossings even when there is a pedestrian crossing nearby. Hence, traffic issues inside the campus increase parallel to the increase in the number of student and personnel vehicles in the university traffic.

Mobile average speed control system has been applied without any enforcement in order to solve the over speeding issues of drivers on campus sections. The first step of this two-stage system applied to eleven different sections with speed limits of 20, 30, and 50 km/h was carried out with the first stage in the "before period" (without any announcement of the average speed control to the drivers), while the second stage was applied during the "after period" (by announcing average speed control to the drivers). It was determined at the end of the application that the speeding behavior of the drivers underwent a moderation despite the presence of no enforcement [3]. Even though the results looked positive, it was observed that the vehicles that tried to obey the speed limit during the first month in the after period (with the announcement) started neglecting this speed limit more and more each day in the following month. In addition, the rate of violation of speed limits increased over time for some sections. This has promoted us to think that the speed limits applied to some sections were not reasonable by the drivers [12]. As a result of all these determinations and opinions, surveys were applied to 729 drivers who regularly enter-exit the campus within the scope of "driver's personal characteristics, self-stated driver behaviors, opinions on other enforcement measures in the campus, and the speed limit application". Since the sections at which measurements were made are all inside a university campus, 99% of the vehicles that enter-exit are light vehicles (weight $\leq$ 3.5 tons). Therefore, the heavy-vehicle

drivers (weight > 3.5 tons) were excluded from all sections and the statistics were calculated only for light vehicles (passenger vehicles and pick-up trucks) [3].

The article presents the opinions on mobile average speed enforcement at low speed sections of drivers who regularly enter/exit the campus. The relationships between these opinions and the following factors were also evaluated:

1. "Driver's personal characteristics";
2. "Behaviors put forth by the drivers regarding their own driving safety and speeding behavior";
3. "Opinions of drivers regarding traffic enforcements".

The "driver's personal characteristics" section of the applied survey was comprised of questions for determining:

- Gender;
- Age;
- Education levels;
- Responsibilities at the university for the participants.

There were also questions for determining the "behaviors put forth by the drivers regarding their own driving safety and speeding behavior":

- Passenger responsibility in the vehicle;
- Tendency to overtake other vehicles;
- Number of accidents as the driver.

However, the "opinions of drivers regarding traffic enforcements" comprised research questions:

- Their opinions on the number of speed bumps along the sections in the campus;
- Their opinions on the average speed enforcement in the campus.

Currently, there is a limited number of article papers published in peer-reviewed journals that analyze and evaluate the drivers' opinions on average speed enforcement.

## 2. Background

The spot speed of a vehicle is the independent vehicle speed measured as the vehicle passes a certain spot on the road, whereas average speed is the corridor speed of a vehicle between two spots separated by a certain distance [3,13]. Average speed enforcement system is a new smart transportation system application that has recently gained popularity in the world and primarily in Europe and Australia [14], followed by Turkey in recent years as well. Average speed enforcement system is comprised of two or more cameras placed along a section of the road network (Figure 2) [15]. Vehicle license plate and/or registration data are acquired as they pass by the first camera location along with additional images and data obtained using the cameras placed along the section, which are then compared with the initial data acquired. Automatic number plate recognition and optical character recognition technology are then used for matching the vehicle registration

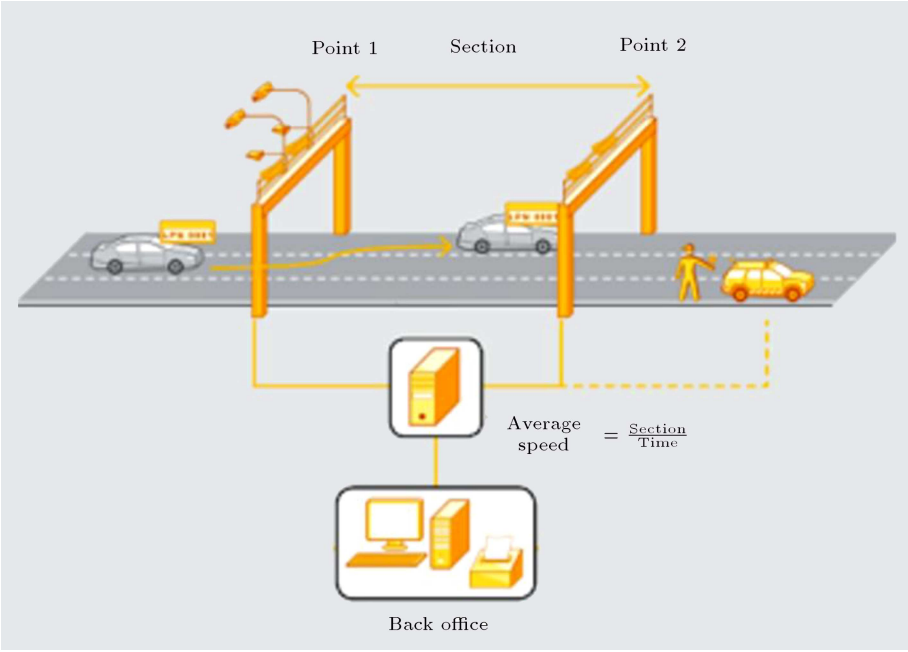


**Figure 2.** Average speed enforcement system.

data [3,14,16–23]. Violation data, e.g. time, date, speed, etc., are uploaded to a central processing unit from the local processor using a communication network if the determined vehicle speed exceeds that of the legal speed limit for that section. A violation notice is then prepared for the verified violations while vehicles with no violation are removed from the database after a certain period of time [3,14,17,18,23].

There are two main approaches to the installation of the average speed enforcement system: "Permanent or mobile systems". Permanent systems are typically installed on road side structures or structures such as fixed bridges and overpasses which have been built for such purposes [17,18,21]. However, the same systems are called mobile systems when placed on a vehicle or trailer and they are mostly used as temporary measures during road work [17,21]. A series of advantages have been recorded for mobile average speed cameras. First of all, it has been suggested that considering the drivers' perception regarding "spot speed measurement systems" as "unfair", such approaches may decrease the negative attitudes of the public towards the current efforts for mobile speed enforcement. In addition, discussions have been made regarding the possibility of an increase in the aversive effects of mobile speed cameras. It was evaluated whether drivers would be encouraged to drive within the speed limits for longer periods of time when they pass by a mobile average speed camera or not since they would not know for sure if the camera measures spot speeds or the average speed between two predetermined points [17].

The number of studies that directly compare Average Speed Enforcement with other camera-based speed applications is limited [16,24]. While Keenan [25] makes interpretations regarding the advantages of average speed technology, it was presented that fixed-spot speed measuring cameras would have specific impacts on the field, but the impact of average speed camera system on the drivers and their speeds could be observed at longer distances. Average speed enforcement prevents the drivers from braking suddenly as soon as they spot the camera and speed up rapidly after passing the camera thereby eliminating the risks involved with such behavior [17,19,25–29]. Studies evaluating this application point out decreases in travel time, especially during busy hours [6,14,30,31] and improvements in traffic flow due to decrease in traffic congestion and holdups [6,17,32,33]. Traffic flow has improved at Junction 28 of the M8 near Glasgow in Scotland following the installment of average speed cameras resulting in decreases of travel times during peak hours from 10–15 minutes to 0–5 minutes [30]. Keenan [25] compared the average speed cameras installed on the Nottingham M1 highway in the United Kingdom in July 2000 with the fixed-spot speed cameras that were in use previously. It was reported that the number of accidents decreased from 33 to 21 during the year following the installment of the cameras [21,25]. Keenan [34] also set forth a statistical analysis of driver behaviors for three spot speed camera zones and one average speed camera application zone. Accordingly, the results set forth for the average speed camera zones with regard to 85th percentile speeds were either at or below the speed limits. However, the results for spot speed camera zones indicated that "speed limit was obeyed only at locations near the camera and that the speeds 500 m before and after the cameras were about 10% greater than the 85th percentile speeds". An experiment was carried out at Junction 28 Whitecart Viaduct within the scope of the Temporary Automatic Speed Camera at Roadworks Project for comparing the effects of spot speed and average speed applications on driver behavior during which spot speed application was used in the first stage and average speed application was used in the second stage. The number of violations during the first stage (with spot speed cameras) was about 11 times more than that in the second stage. Compliance with speed limit not only improved during the second stage but there was also a chain reaction as a result of which the number of crashes decreased and delays during the heavy morning commutes decreased. In addition, it was also indicated that crashes without injuries decreased from 13% to zero. This is an indication that average speed enforcement creates a safer environment with continuous flow behavior and minimal speed difference [16,24,34]. Section control using average speed cameras will not replace the speed limit investment method involving fixed speed cameras; this is an additional method for enforcing the speed limits. However, it is considered, especially in Holland, to replace some of the spot speed cameras with average speed cameras. Not all sections are suited for section control due to intersections and/or bends/hills [35]. A study was carried out in the city of Khonkaen in Thailand for determining the impacts of average speed enforcement on a 14 km long urban arterial road. The average speeds were measured for the drivers after determining their spot speeds via spot speed cameras. It was observed that the number of drivers driving at speeds of above 100 km/hour decreased by about 52% after average speed enforcement. Moreover, the number of deaths in traffic-related accidents in the following two years after the implementation decreased by about 78% [36].

### *2.1. Speed limit perception of drivers*

Speed preferences of the drivers are not rational in an objective manner. Indeed, there would be no need for speed enforcement applications if they were able to select the best speeds from a social perspective [19]. However, speed enforcement is not a measure that can be applied by itself; it should also be supported by

other measures after the selection of reliable speed limits. Speed limits that appear as inconsistent in reality can be ignored by the drivers; speed limits that reflect the environment of the road and the expectations of the driver may help promote the respect of the drivers for speed limits [1,19,37]. Despite the increases in the scope and intensity of speed enforcement applications, a series of studies carried out in Australia presented evidence that speeding behavior was still present as common behavior and majority of the drivers chose speeds that were 10 km/h above the speed limit [8,17,38–40]. As a result of the aforementioned studies, it was concluded that speeding could be accepted socially when it was not considered excessive [3,41,42].

It is important for the drivers to understand the technology that is presented to them on the road; because this also helps enhance their attitudes and behaviors. It was apparent that drivers did not have sufficient knowledge of the applied technology until the acceptance of the average speed enforcement sign (sign plate) in 2006 in Europe. It could be seen that they were braking in front of the camera (a behavior similar to that observed by spot speed cameras) and much erroneous information about this technology was shared on internet sites and forums [24]. However, there is a better understanding today about how cameras monitor speed thanks to the placement of average speed enforcement signs which helps not only obeying the speed limits but also the flow of traffic. Since drivers are now aware that they have to reduce their speeds before the first camera and keep their speeds consistent along the whole road, braking in front of the camera is now rarely observed. This approach enables the drivers to change their behaviors prior to a violation that will result in a speeding ticket and this sign now has a high ratio of recognition since it is used on all road networks. The objective is to prevent speeding behavior rather than catching the violators [24,43,44].

### 2.2. General opinions and perceptions of drivers regarding average speed enforcements

Every individual has an opinion on speed enforcement regardless of whether they are drivers or not and hence, this issue generally has priority in public, media, and political discussions. The public hold various opinions in this matter, e.g., some believe it is obligatory to decrease the number of speeding drivers and some others think that speed enforcement is only another means of income for the government. While those who commit speeding offence develop a negative perception of cameras, some others, possibly, hold an opposite idea given they might have experienced an accident due to speeding or know people who have had it before. Media and political opinions will, of course, vary among different sides; yet, they will have a significant effect on the public opinion. This portrait of speed enforcement proffered by the parties will affect not only the public opinion but also driver behavior in sections with camera application. For example, if the idea that the system may be 'manipulated' due to some reports in the press goes rampant, it will have adverse effects on the speeding behaviors of the majority of the drivers [1,24].

A driver survey carried out in the United Kingdom puts forth that 74% of the drivers obey speed enforcement. However, 18% of the participants have stated that speed enforcement encourages them to drive in compliance with speed limits on roads with no speed enforcement. In addition, 56 of the participants are of the opinion that spot speed enforcement takes place only inside the vicinity of the camera [24].

A survey carried out in France on over 1000 drivers on their opinions related with speed enforcement applications has put forth positive findings (despite the fact that it is only a suggestion and that there is no enforcement element). A total of 61% of the drivers have stated that they believe the application is a good intervention; 73% have pointed to their decisions on speed reduction; 54% have held that they believe it encourages driver responsibility and 17% have attested that the system ensures road safety [33].

Other driver surveys carried out in Europe also set forth that 70% of the drivers supported speed enforcement, thus reaching similar results with those in France [14]. A survey carried out concerning English drivers revealed that 72% of the participants supported average speed enforcements on 20 mph settlement section roads [45]. It was demonstrated that in Finland, 84% of the drivers accepted the new technology and that only 10% viewed this approach as unacceptable [17].

On the other hand, a survey carried out in the New South Wales state of Australia for 315 drivers who regularly drive point outed that 63% of the participants supported average speed enforcement [40]. In addition, surveys carried out in Queensland by "Royal Automobile Club of Queensland" revealed that 66% of the members supported average speed enforcement, especially in rural areas [14].

Montella et al. [19] carried out a study in Italy for analyzing average travel speeds on sections of A56 and A3 highways. Driver perceptions were evaluated in this study using face-to-face interviews at four resting spots two of which were located on Highway A3 and two on A56. These face-to-face interviews comprise a total of 2200 drivers with 1100 on A3 and 1100 on A56. Sample group was structured as five sections:

1. Driver data;
2. Vehicle data;
3. Speed perception of drivers;

4. Speed enforcement perception of drivers;
5. Risk of fine perception in case of speeding.

The ratio of drivers not aware that such an application was in effect was 35% on A3 and 26% on A56, whereas the ratio of drivers who did not know that the enforcement was for an average speed that exceeded the speed limit only between the cameras was 25% on A3 and 22% on A56. It was determined that as a result of the evaluation of the perceptions of drivers related with the risk of fines in case of speeding, there was a greater risk on A56, while 25% of the drivers on A3 were of the opinion that the risk of being fined was greater and 39% of the drivers on A56 indicated a higher risk of being fined. In addition, 37% of the drivers expressed that the risk of being fined was the same on both highways. Data related with speed enforcement and fine perceptions of drivers were parallel to those of over speeding.

Average speed enforcement remains open to discussion in Norway as well. According to experiences acquired in Norway, driver speed level may generally be excessive in tunnels and this is especially true for sub-sea road tunnels. This makes enforcements related with speeding necessary and desirable when combined with the potential of accidents in tunnels escalating to disaster status. Hence, average speed enforcement is particularly suitable as a precaution according to Ragnøy [46]. Those who oppose the application are concerned about issues related with privacy and they have doubts about the effectiveness of this application in tunnels where high accident records are not required for system installation. Those who defend the application are of the opinion that section enforcement might make a difference for downhill sections of tunnels and that the accident may have spreading effects rather than displacement for downward sections [47].

### 2.3. Perceptions of drivers regarding the differences between other speed measures and average speed enforcement

#### 2.3.1. Spot speed cameras

The speeding behaviors of drivers are socially accepted especially when they exceed the limits only slightly [14,41,42]. Moreover, drivers frequently criticize that enforcements for which instantaneous speed is measured generally "are unsuccessful in taking into account the circumstances that attenuate speeding and that they do not exhibit typical speeding behavior" [14]. Measuring speed over longer distances on sections where average speed enforcement is applied suggests that speeding is in general a voluntary behavior and that it is not due to a spot lack of concentration [20,32,34,48]. Thus, a series of driver surveys suggest a high level of driver acceptance regarding the application [1,14,32].

Swift cover motor insurance company in England carried out a survey in June 2007 that examines the attitudes of drivers towards different types of speed cameras. However, 53% of the drivers believed that spot speed cameras encouraged the drivers towards a more unstable type of driving; 56% stated that they broke the law when they recognized the camera and speed right after they passed it. Of the same drivers, 75% stated that they drove within the speed limits on all roads where average speed cameras were used and average speed cameras were defined as the most effective deterrent system as a result of the survey study [24].

Following the first-stage implementation of the average speed enforcement in Holland, it was found that 75% of the drivers perceived this application to be fairer than other automated speed enforcement types and that the driver acceptance was high. Perception of increased justice in combination with the measurement of speeding behavior over a wider section of the road network is the underlying factor of such positive perceptions rather than the measurements made using spot speed cameras. Several drivers pointed to their anxieties regarding the confidentiality of the information caught by the camera systems and that braking behavior around the camera regions was mitigated (stop-start) [9,14,17].

#### 2.3.2. Speed bump applications

An important obstacle to reducing speed limits in the first years of the average speed enforcement and widening the 20 mph network was that the standard cameras did not receive approval for speeds under 30 mph. Hence, speed bumps and sharp turns were used. However, such speed enforcement methods were not taken kindly by the drivers despite their effectiveness; they slightly increased emissions and caused obstacles for service and emergency vehicles. The trial of this system at low-speed urban sections (e.g., 20 mph sections) has undergone some changes lately. It has been set forth that the technology provides an effective alternative to relatively expensive speed bumps which may increase emissions and cause unnecessary obstacles to emergency vehicles [20,45]. Road transportation sector makes up about 25% of the manmade $CO_2$ (carbon dioxide) emission in the world. In this regard, a series of studies on this subject have demonstrated that a decrease in traffic noise and harmful vehicle emissions resulting from improvements in traffic flow may be related to average speed enforcement despite the fact that related proofs are quite varied [49]. As a result of driver surveys carried out in Europe, it was determined that only 43% of the drivers supported speed bumps as an alternative to speed enforcement [45]. Speed humps pose a greater challenge for bicycles and buses than cars. It would

therefore be an improvement if the average speed enforcement, even over short distances, could make the installation of speed humps unnecessary.

According to Akpa et al. [50], while the system aims to manage vehicle speeds through precautions such as speed bumps, other precautions such as spot speed cameras should be employed to ensure compliance with the implemented speed limits. In addition, according to the obtained reports, these precautions are generally effective in the intervention area, but they are costly and not practical for long distance use.

In general, studies indicate that drivers have positive attitudes towards the use of average speed enforcement and accordingly, it has higher public support than other speed enforcement approaches [17,20,48].

## 3. Method

Table 1 presents the characteristics of 11 road sections on which mobile average speed enforcement was applied, including length, speed limit, number of lanes, lane width, number of intersections, horizontal curves, pedestrian crossings, speed bumps, and diameters of horizontal curves. Furthermore, the images of these sections on the campus map, including traffic flow directions, are also given in Figure 3. All sections have different physical/engineering characteristics. These sections on which the system was set up do not have different average traffic volume since they are all inside a university campus. The flow rate in the campus was 0–600 vehicles/hour per lane. The focus should be on free flowing conditions of traffic rather than congestion in order to make an accurate assessment of the impact of average speed enforcement through a before-after comparison. Vehicles follow each other during congestion with travel speeds that are mostly below the speed limit. This, in turn, results in an average speed that is lower than the allowed limit for the specific road section subject to measurement [51,52].

The average speed enforcement technology installed has two basic forms:

(a) Moving the camera from one fixed spot to another;

(b) Mounting a camera on a vehicle.

Enforcing driver speed behavior on a wide area without the necessity for holistic systems at every fixed spot was the concept behind moving the camera between fixed spots. This may be due to economic or administrative reasons. The economic perspective is simple – it requires a smaller number of cameras. However, disagreements of drivers with regard to speed traps are considered as administrative reasons. License plate recognition was attained using the cameras placed inside a 'sound system luggage' installed on two passenger vehicles, thus ensuring the required angle for license plate recognition as well as the technically sufficient results desired from the readings (for a high license plate capture rate) (Figure 4). In this manner, pedestrians and motorists would not stand a chance to spot the system (because of the covertness of measurements during the 'before' period) [3,53].

Two-lane number plate recognition cameras were selected, capturing a wide angled image which covered both the entire vehicle and its lane position. The license plates of the vehicles are detected through the uninterrupted video flow method after which the photographs are transferred to the central server. The license plates analyzed using cameras are then transferred to the central server (computer+main software) over a wireless internet connection (3G Router) as both text and photograph (shown in Figure 5) [3,53].

The number of vehicles with identified average speeds was 23,060 during the 'before' period and 21,089 during the 'after' period.

Table 2 [54] shows the results of the 'before'/'after' speed measurements covering a total of 11 average speed enforcement sections. Section C with the highest speed of 54.27 km/h during the 'before' period

**Table 1.** Characteristics of sections.

| Section | Length (m) | Speed limit (km/h) | Number of lanes | | Lane width (m) | | Number of intersections | Number of horizontal curves | Diameters of horizontal curves (m) | Number of pedestrian crossings | Number of speed bumps |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | First point | Second point | First point | Second point | | | | | |
| A | 908 | 30 | 2 | 1 | 3.50 | 3.50 | 4 | 2 | 288/108 | 5 | 3 |
| B | 717 | 30 | 2 | 2 | 3.50 | 3.50 | 3 | — | — | 4 | 3 |
| C | 890 | 50 | 2 | 2 | 3.50 | 3.50 | 1 | — | — | 4 | 1 |
| D | 890 | 50 | 2 | 2 | 3.50 | 3.50 | 2 | — | — | 4 | 1 |
| E | 425 | 30 | 2 | 2 | 3.50 | 3.50 | 2 | — | — | 2 | 2 |
| F | 600 | 20 | 2 | 2 | 3.00 | 3.00 | — | — | — | 3 | — |
| G | 600 | 20 | 2 | 2 | 3.00 | 3.00 | — | — | — | 3 | — |
| H | 615 | 30 | 1 | 2 | 3.50 | 3.50 | 3 | 3 | 40/30/106 | 3 | 1 |
| I | 594 | 30 | 2 | 1 | 3.50 | 3.50 | 3 | 3 | 106/30/40 | 3 | — |
| J | 695 | 30 | 2 | 1 | 3.50 | 3.50 | 2 | 2 | 30/22 | 3 | — |
| K | 695 | 30 | 1 | 2 | 3.50 | 3.50 | 2 | 2 | 22/30 | 3 | — |


**Figure 3.** Average speed sections.


**Figure 4.** Automatic number plate recognition setup placed on the vehicle [3,53].

was where the greatest speed reduction of 4.83 km/h (8.90%) was observed among other sections in the 'after' period. The lowest speed reduction in travel speed was measured in Section I with 0.99 km/h (2.31%). Increases in average speed values were observed in Sections A and B with values of 0.35 and 0.17, respectively (these increases in speed were not significant). However, the decrease in average speeds at sections with 20, 30, and 50 km/h were identified respectively as 2.15 km/h (4.50%), 1.81 km/h (5.10%), and 4.50 km/h (8.35%).

The findings of 'before'/'after' measurements of the mobile system installed on 11 different sections according to their violation statuses are as follows: 69.38% of vehicles were violating speed limits in all sections during the 'before' period, whereas this rate decreased down to 63.01% in the 'after' period. However, the percentage of the vehicles complying with the speed limits was 30.62% during the 'before' period, although it increased up to 36.99% during the 'after' period.

### *3.1. Data acquisition: Survey application*

A survey of the drivers in a region where the average speed enforcement is applied to evaluating their opinions about whether the system is acceptable or not was conducted. The surveys were distributed among the drivers at all five gates of the university during the dates of 20.05.2013–24.05.2013 with support by the rectorate and the security staff (so that the surveys would be taken seriously by the drivers) and the drivers were asked to leave the filled-out surveys to the staff at the entrance gates. Of the 734 surveys filled out by the drivers, 729 were valid.

Areas such as campuses are regions where commuter (drivers who enter-exit the campus regularly) driver groups are present, which enables the measure-

**Table 2.** 'Before'/'after' average speed data and speed reductions [3,54].

| 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 |
| **Average** | **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 |
| **Average** | **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 |
| **Average** | **50** | | **53.87** | **49.37** | **4.50** | **8.35** |


**Figure 5.** Vehicle example transferred as a photograph via 3G router [3].

ment of average speeds of the same vehicles more than once. The study group was designed based on the drivers who enter-exit the campus regularly while designing the survey study. These drivers represent the group including "administrative staff, academic staff, university students, and others (employers at businesses such as campus cafeterias etc.)". The sample group for this case study was acquired in accordance with the random sampling method. The average speed system technology was installed on all roads of the campus such that no control group was required.

### *3.2. Data analysis*

Data acquired from the surveys were inputted to the SPSS (Statistical Package for the Social Sciences) software package and statistical analyses in accordance with the goals of the study were carried out. First, descriptive statistical methods of "frequency and percentage" were employed for evaluating the survey data. Afterwards, chi-square test was carried out for analyzing the relationship between the variables related with the drivers who participated in the survey and "opinions of drivers related with the speed limits applied in the campus via average speed cameras", thus examining the statistical significance of the chi-square value. Chi-square independence test was employed for examining whether there is any relationship between two or more categorical variable groups. Statistically, there will be no significant relationships between the variables if the $p$-value in the chi-square table is greater than 0.05.

The tests used here for examining the existence of any relation are listed below:

- Is there a relationship between the "age, gender, education level, responsibility level" and the "opinions of the drivers regarding the speed limits enforced by the average speed system applied in the university"?
- Is there a relationship between the "gender, age, education level, and responsibility level" of the drivers and the "behaviors they put forth regarding the tendency to overtake other vehicles"?
- Is there a relationship between the "feeling passenger responsibility as the vehicle driver, tendency to overtake other vehicles, and number of involved accidents as the driver" and the "opinions of drivers regarding the speed limits enforced in the university via average speed system"?

- Is there a relationship between the "opinions of drivers on the speed bumps applied in the university" and the "opinions of drivers on the average speed system and the speed limits enforced in the university"?

## 4. Results

### *4.1. Personal characteristics of the drivers who participated in the study, frequency, and percentages*

Table 3 shows the "driver's personal characteristics" for 729 survey participants. Of these drivers, 67.7% were males and 32.3% females. It was found that 28% of the drivers were in the 21-30 age category, 32% in the 31-40 age category, and 26.9% in the 41-50 age category. After examining their education levels, it was concluded that 23.6% of the drivers were primary and high school graduates, 12.4% were college graduates, 26.6% were university graduates, and 37.3% were postgraduate alumni. Of the drivers, 40.7% were employed as academics, 22.2% the administrative staff, and 14.4% students. "Daily vehicle use durations" are accessible in Table 3. It was determined that the daily vehicle use durations of 42% of the drivers were one hour and below, 28.7% were between one-two hours and that 29.4% were above two hours. Only the frequency and percentage values were calculated for the distances covered by the drivers in their vehicles since it may vary according to their address of residence.

The behaviors of the drivers put forth for "their own driving safety and speeding behavior" are given in Table 4. Of the drivers, 93.9% expressed that they are responsible for the passengers in the vehicle, whereas 0.8% did not feel any responsibility with 5.2% feeling somewhat responsibility sometimes. Of the participants, 16.9% responded yes to this question: "Do you tend to overtake other vehicles at every opportunity?" 42.7% responded no and 40.4% responded sometimes. It was determined that 38.6% of the drivers never had any accidents, 34.2% one accident, and 16.5% two accidents.

Table 5 shows the "opinions regarding traffic enforcement and precautions" of the drivers. 50% of the drivers held that the number of speed bumps in the campus was more than enough; 45% considered it to be sufficient, and 4.4% believed it to be not sufficient. Based on the opinions of the drivers collected about the speed limits enforced in the campus via average speed cameras, it was found that speed limits were high, low, and sufficient for 1.6%, 52%, and 42.6% of the drivers, respectively [55].

### *4.2. Analysis of driver's personal characteristics*

Values related to the variables of "gender" and "opinions on the applied speed limits" are observed in Table 6. It was determined that 100% of the drivers believing that the applied speed limits were high were male; there were no female drivers who were of the opinion that the speed limits were high. It was also determined that 60.8% of those who consider the speed limits to be low were male, whereas 39.2% were female on the opposing end. It was also suggested that 75.9% of those who considered speed limits sufficient were male. Chi-square test indicated a statistically significant difference between the opinions of females and males in terms of average speed cameras and speed enforcement. When the ratios related to the "age" variable in the table were examined, it was observed that the response ratios of the drivers for each age group were close to each other. In addition, no statistically significant difference was determined as a result of the chi-square test between the opinions on average speed cameras and speed enforcement. The table shows the ratios related to the "education level", which is

**Table 3.** Personal characteristics of the drivers who participated in the survey.

| Descriptive statistics | N | % |
|---|---|---|
| **Gender** | | |
| Male | 493 | 67.7 |
| Female | 235 | 32.3 |
| **Age** | | |
| 20 and under | 11 | 1.5 |
| 21–30 | 204 | 28.0 |
| 31–40 | 239 | 32.8 |
| 41–50 | 196 | 26.9 |
| 51–60 | 62 | 8.5 |
| 61 and above | 17 | 2.3 |
| **Education level** | | |
| Primary school | 29 | 4.0 |
| High school | 143 | 19.6 |
| College | 90 | 12.4 |
| University | 194 | 26.6 |
| Postgraduate | 103 | 14.1 |
| Doctorate | 169 | 23.2 |
| **Title at the university** | | |
| Academic | 288 | 40.7 |
| Administrative | 157 | 22.2 |
| Student | 103 | 14.5 |
| Other | 160 | 22.6 |
| **Daily vehicle use duration** | | |
| 1 hour and less | 303 | 42.0 |
| Between 1–2 hours | 207 | 28.7 |
| Between 2–3 hours | 82 | 11.4 |
| More than 3 hours | 130 | 18.0 |

**Table 4.** Driving safety/speeding behaviors of drivers who participated in the survey.

| Behaviors put forth by the drivers regarding their own driving safety and speeding behaviors | N | % |
|---|---|---|
| **Passenger responsibility in the vehicle** | | |
| Yes | 683 | 93.9 |
| No | 6 | 0.8 |
| Sometimes | 38 | 5.2 |
| **Tendency to overtake the other vehicles** | | |
| Yes | 123 | 16.9 |
| No | 311 | 42.7 |
| Sometimes | 294 | 40.4 |
| **Number of accidents as the driver** | | |
| 0 accident | 231 | 38.6 |
| 1 accident | 205 | 34.2 |
| 2 accidents | 99 | 16.5 |
| 3 accidents | 41 | 6.8 |
| 4 accidents and above | 23 | 3.8 |

**Table 5.** Opinions on traffic enforcement of drivers who participated in the survey [55].

| Opinions of drivers on traffic enforcements and precautions | N | % |
|---|---|---|
| **Number of speed bumps** | | |
| Not enough | 32 | 4.4 |
| Enough | 327 | 45.0 |
| More than enough | 368 | 50.6 |
| **Speed limits** | | |
| High | 11 | 1.6 |
| Low | 362 | 52.8 |
| Sufficient | 292 | 42.6 |
| No Idea | 20 | 2.9 |

an indication that 58.6% of the drivers with primary school education are of the opinion that the speed limit is sufficient, whereas 53.6% of college graduates think that speed limit is sufficient in this application; besides, 52.5% of those at the university level, 65% at the graduate level, and 59.5% at the doctorate level are of the opinion that speed limit is low. Although the majority of the drivers with university education considered speed limit to be low, the majority of those with primary school and college education considered speed limits sufficient. As a result of the chi-square test, it was indicated that there was a statistically significant difference between the opinions on average speed cameras and speed enforcement. When the ratios related with the "title at the university" were examined, it was determined that 62.5% of the academics, 50.3% of the administrators, and 57.3% of the students considered the speed limit sufficient. Of those working in administrator positions, 43.6% thought that speed limits were sufficient. According to the results of the chi-squared test, it was found that there were statistically significant differences between the opinions on average speed cameras and speed enforcement with respect to duties at the university.

Values related with the variables of "gender, age, education level, responsibility at the university", and "tendency to overtake vehicles" are given in Table 7. After investigating the values in the table, it was observed that 40% of the male drivers responded as no to the tendency to overtake vehicles and 40.2% responded as sometimes, whereas 48.1% of the female drivers responded as no and 40.9% responded as sometimes. Based on the chi-square value, it was determined that gender difference affected the tendency to overtake vehicles. Upon examining the values in the table, it was observed that 81.8% of the drivers under the age of 20 responded as sometimes, 42.6% between the ages of 21-30 responded as sometimes, and 45.2% between the ages of 31-40 responded negatively, whereas 47.2% of the drivers between the ages of 41-50 responded negatively and 70.6% aged 61 and above responded negatively. Moreover, there was a

**Table 6.** Chi-square test results of "driver's personal characteristics" and "opinions on average speed enforcement".

| Chi-square test | | | Opinions on speed limit | | | | Total |
|---|---|---|---|---|---|---|---|
| | | | High | Low | Sufficient | No idea | |
| **Gender** | Male | N | 11 | 220 | 221 | 12 | 464 |
| | | % | 100.0 | 60.8 | 75.9 | 60.0 | 67.8 |
| | Female | N | 0 | 142 | 70 | 8 | 220 |
| | | % | 0.0 | 39.2 | 24.1 | 40.0 | 32.2 |
| **Total** | | N | 11 | 362 | 291 | 20 | 684 |
| | | % | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 |
| $\chi^2/p$ | | | **22.824/0.000** | | | | |
| **Age** | 20 and below | N | 0 | 5 | 4 | 0 | 9 |
| | | % | 0 | 55.60 | 44.40 | 0.0 | 100.0 |
| | 21–30 | N | 2 | 111 | 66 | 5 | 184 |
| | | % | 1.1 | 60.3 | 35.9 | 2.7 | 100.0 |
| | 31–40 | N | 4 | 111 | 105 | 6 | 226 |
| | | % | 1.8 | 49.1 | 46.5 | 2.7 | 100.0 |
| | 41–50 | N | 3 | 100 | 79 | 7 | 189 |
| | | % | 1.6 | 52.9 | 41.8 | 3.7 | 100.0 |
| | 51–60 | N | 2 | 26 | 31 | 2 | 61 |
| | | % | 3.3 | 42.6 | 50.8 | 3.3 | 100.0 |
| | 61 and above | N | 0 | 9 | 7 | 0 | 16 |
| | | % | 0.0 | 56.3 | 43.8 | 0.0 | 100.0 |
| **Total** | | N | 11 | 362 | 292 | 20 | 685 |
| | | % | 1.6 | 52.8 | 42.6 | 2.9 | 100.0 |
| $\chi^2/p$ | | | **10.596/0.781*** | | | | |
| **Graduation** | Primary | N | 2 | 9 | 17 | 1 | 29 |
| | | % | 6.9 | 31.0 | 58.6 | 3.4 | 100.0 |
| | High School | N | 4 | 62 | 60 | 3 | 129 |
| | | % | 3.1 | 48.1 | 46.5 | 2.3 | 100.0 |
| | College | N | 1 | 35 | 45 | 3 | 84 |
| | | % | 1.2 | 41.7 | 53.6 | 3.6 | 100.0 |
| | Bachelor's | N | 2 | 96 | 82 | 3 | 183 |
| | | % | 1.1 | 52.5 | 44.8 | 1.6 | 100.0 |
| | Graduate | N | 2 | 63 | 28 | 3 | 96 |
| | | % | 2.1 | 65.6 | 29.2 | 3.1 | 100.0 |
| | Doctorate | N | 0 | 97 | 59 | 7 | 163 |
| | | % | 0.0 | 59.5 | 36.2 | 4.3 | 100.0 |
| **Total** | | N | 11 | 362 | 291 | 20 | 684 |
| | | % | 1.6 | 52.9 | 42.5 | 2.9 | 100.0 |
| $\chi^2/p$ | | | **32.303/0.006** | | | | |

*: Significant at the 5% level.

**Table 6.** Chi-square test results of "driver's personal characteristics" and "opinions on average speed enforcement" (continued).

| Chi-square test | | | Opinions on speed limit | | | | Total |
|---|---|---|---|---|---|---|---|
| | | | High | Low | Sufficient | No idea | |
| Title | Academic | N | 1 | 170 | 95 | 6 | 272 |
| | | % | 0.4 | 62.5 | 34.9 | 2.2 | 100.0 |
| | Administrative | N | 1 | 75 | 65 | 8 | 149 |
| | | % | 0.7 | 50.3 | 43.6 | 5.4 | 100.0 |
| | Student | N | 2 | 51 | 34 | 2 | 89 |
| | | % | 2.2 | 57.3 | 38.2 | 2.2 | 100.0 |
| | Other | N | 7 | 57 | 88 | 4 | 156 |
| | | % | 4.5 | 36.5 | 56.4 | 2.6 | 100.0 |
| Total | | N | 11 | 353 | 282 | 20 | 666 |
| | | % | 1.7 | 53.0 | 42.3 | 3.0 | 100.0 |
| $\chi^2/p$ | | | 39.350/0.000 | | | | |

*: Significant at the 5% level.

statistically significant difference in the tendency to overtake vehicles of drivers with regard to age. Based on the tendency to overtake vehicles as illustrated in the table, 42.9% of the primary school graduates responded as sometimes, 43.4% of high school graduates responded as sometimes, 40% of college graduates responded negatively and 40% as sometimes, 43.3% of the undergraduates responded negatively, 47.6% of the master's degree graduates responded negatively, and 51.5% of doctorate graduates responded negatively. A statistically significant difference was found between the tendencies to overtake vehicles with regard to the education levels of students according to the chi-square test results. Finally, 51% of those working in academic positions responded negatively to the tendency to overtake vehicles and 42.7% of those working in administrative positions responded as sometimes, whereas 50.5% of students responded as sometimes. A statistically significant difference was determined between the tendencies to overtake vehicles with regard to the occupational status according to the chi-square test results.

### *4.3. Analysis of drivers' driving safety/speeding behavior*

Results of the two variables of "tendency to overtake other vehicles" and "opinions on speed enforcement" can be seen in Table 8. According to the ratios in the table, 42.5% (154 people) of those who state that the speed limit is low have a tendency to sometimes overtake other vehicles and 46.4% (135 people) of those who think that the speed limit is sufficient do not have a tendency to overtake other vehicles. No statistically significant difference was identified between the opinions of drivers on average speed cameras and speed enforcement according to their tendencies to overtake other vehicles as a result of the chi-square test. Values of the two variables of "opinions on the applied speed enforcement" and "accidents made as the driver" are also shown in Table 8. When the ratios in the table are examined, it can be seen that 77.8% of those who have an accident are of the opinion that the speed limit is high, whereas 52.9% of those who have had no accident do not have any opinion about speed enforcement. However, the chi-square test showed that there was no statistically significant difference between the opinions on average speed cameras and speed enforcement of those who have and do not have an accident. The relationships of drivers "who feel and do not take passenger responsibility" with "opinions on speed enforcement" can be seen in the same table. After investigating the ratios, it can be observed that 81.8% of those who state that the speed limit is high take passenger responsibility, whereas 93.6% of those who state that the speed limit is low take passenger responsibility in the vehicle. By the same token, according to the results of the chi-square test, there is no statistically significant difference between the opinions on average speed cameras and speed enforcement of drivers who do and do not take passenger responsibility in the vehicle. This indicates that drivers' feeling responsible for passenger safety is not affected by their opinions on speed enforcement.

### *4.4. Analysis of the opinions of drivers on traffic enforcement and measures*

Values of the two variables of "opinions on applied speed limit" and "opinions on frequency of speed bumps" can be seen in Table 9. Of those who think that speed limits are high, 81.8% (nine people) are of the opinion that the number of speed bumps is sufficient. This may lead us to think that the drivers in this group prefer speed bumps to average speed enforcement. Of those who think that speed limits are low, 62.2 (224

**Table 7.** Chi-square test results of "gender, age, education, responsibility at the university" and "tendency to overtake vehicles".

| Chi-square test | | | Tendency to overtake vehicles | | | Total |
|---|---|---|---|---|---|---|
| | | | Yes | No | Sometimes | |
| **Gender** | Male | N | 97 | 197 | 198 | 492 |
| | | % | 19.7 | 40.0 | 40.2 | 100.0 |
| | Female | N | 26 | 113 | 96 | 235 |
| | | % | 11.1 | 48.1 | 40.8 | 100.0 |
| **Total** | | N | 123 | 310 | 294 | 727 |
| | | % | 16.9 | 42.6 | 40.4 | 100.0 |
| | $\chi^2/p$ | | **9.464/0.009** | | | |
| **Age** | 20 and below | N | 2 | 0 | 9 | 11 |
| | | % | 18.2 | 0.0 | 81.8 | 100.0 |
| | 21–30 | N | 46 | 71 | 87 | 204 |
| | | % | 22.5 | 34.8 | 42.6 | 100.0 |
| | 31–40 | N | 39 | 108 | 92 | 239 |
| | | % | 16.3 | 45.2 | 38.5 | 100.0 |
| | 41–50 | N | 27 | 92 | 76 | 195 |
| | | % | 13.8 | 47.2 | 39.0 | 100.0 |
| | 51–60 | N | 8 | 28 | 26 | 62 |
| | | % | 12.9 | 45.2 | 41.9 | 100.0 |
| | 61 and above | N | 1 | 12 | 4 | 17 |
| | | % | 5.9 | 70.6 | 23.5 | 100.0 |
| **Total** | | N | 123 | 311 | 294 | 728 |
| | | % | 16.9 | 42.7 | 40.4 | 100.0 |
| | $\chi^2/p$ | | **25.388/0.005** | | | |
| **Education** | Primary school | N | 5 | 11 | 12 | 28 |
| | | % | 17.9 | 39.3 | 42.9 | 100.0 |
| | High school | N | 37 | 44 | 62 | 143 |
| | | % | 25.9 | 30.8 | 43.4 | 100.0 |
| | College | N | 18 | 36 | 36 | 90 |
| | | % | 20.0 | 40.0 | 40.0 | 100.0 |
| | Undergraduate | N | 35 | 84 | 75 | 194 |
| | | % | 18.0 | 43.3 | 38.7 | 100.0 |
| | Master's degree | N | 14 | 49 | 40 | 103 |
| | | % | 13.6 | 47.6 | 38.8 | 100.0 |
| | Doctorate | N | 14 | 87 | 68 | 169 |
| | | % | 8.3 | 51.5 | 40.2 | 100.0 |
| **Total** | | N | 123 | 311 | 293 | 727 |
| | | % | 16.9 | 42.8 | 40.3 | 100.0 |
| | $\chi^2/p$ | | **24.747/0.006** | | | |

**Table 7.** Chi-square test results of "gender, age, education, responsibility at the university" and "tendency to overtake vehicles" (continued).

| Chi-square test | | | Tendency to overtake vehicles | | | Total |
|---|---|---|---|---|---|---|
| | | | Yes | No | Sometimes | |
| **Responsibility** | Academic | N | 31 | 147 | 110 | 288 |
| | | % | 10.8 | 51.0 | 38.2 | 100.0 |
| | Administrative | N | 31 | 59 | 67 | 157 |
| | | % | 19.7 | 37.6 | 42.7 | 100.0 |
| | Student | N | 25 | 26 | 52 | 103 |
| | | % | 24.3 | 25.2 | 50.5 | 100.0 |
| | Other | N | 33 | 67 | 59 | 159 |
| | | % | 20.8 | 42.1 | 37.1 | 100.0 |
| **Total** | | N | 120 | 299 | 288 | 707 |
| | | % | 17.0 | 42.3 | 40.7 | 100.0 |
| $\chi^2/p$ | | | **28.462/0.000** | | | |

**Table 8.** Chi-square test results of "driving safety/speed behaviors of drivers stated by themselves" and "opinions on average speed enforcement".

| Chi-square test | | | Opinions on average speed enforcement | | | | Total |
|---|---|---|---|---|---|---|---|
| | | | High | Low | Sufficient | No Idea | |
| **Overtaking the other vehicle** | Yes | N | 3 | 68 | 42 | 2 | 115 |
| | | % | 27.3 | 18.8 | 14.4 | 10.0 | 16.8 |
| | No | N | 4 | 140 | 135 | 12 | 291 |
| | | % | 36.4 | 38.7 | 46.4 | 60.0 | 42.5 |
| | Sometimes | N | 4 | 154 | 114 | 6 | 278 |
| | | % | 36.4 | 42.5 | 39.2 | 30.0 | 40.6 |
| **Total** | | N | 11 | 362 | 291 | 20 | 684 |
| | | % | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 |
| $\chi^2/p$ | | | **7.986/0.239*** | | | | |
| **Accident** | No accident | N | 2 | 117 | 92 | 9 | 220 |
| | | % | 22.2 | 39.7 | 37.1 | 52.9 | 38.7 |
| | Accident | N | 7 | 178 | 156 | 8 | 349 |
| | | % | 77.8 | 60.3 | 62.9 | 47.1 | 61.3 |
| **Total** | | N | 9 | 295 | 248 | 17 | 569 |
| | | % | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 |
| $\chi^2/p$ | | | **2.868/0.412*** | | | | |
| **Passenger responsibility** | Yes | N | 9 | 338 | 274 | 19 | 640 |
| | | % | 81.8 | 93.6 | 94.2 | 95.0 | 93.7 |
| | No | N | 0 | 2 | 4 | 0 | 6 |
| | | % | 0.0 | 0.6 | 1.4 | 0.0 | 0.9 |
| | Sometimes | N | 2 | 21 | 21 | 1 | 37 |
| | | % | 18.2 | 5.8 | 5.8 | 5.0 | 5.4 |
| **Total** | | N | 11 | 361 | 291 | 20 | 683 |
| | | % | 100.0 | 100.0 | 100.0 | 100.0 | 100.0 |
| $\chi^2/p$ | | | **5.602/0.469*** | | | | |

*: Significant at the 5% level.

**Table 9.** Chi-square test results of "opinions on other traffic enforcement and measures" and "opinions on average speed limit" [55].

| Chi-square test | | | Opinions on the frequency of speed bumps | | | Total |
|---|---|---|---|---|---|---|
| | | | Low | Sufficient | High | |
| Opinions on speed limit | High | N | 1 | 9 | 1 | 11 |
| | | % | 9.1 | 81.8 | 9.1 | 100.0 |
| | Low | N | 10 | 126 | 224 | 360 |
| | | % | 2.8 | 35.0 | 62.2 | 100.0 |
| | Sufficient | N | 19 | 161 | 112 | 292 |
| | | % | 6.5 | 55.1 | 38.4 | 100.0 |
| | No idea | N | 0 | 9 | 11 | 20 |
| | | % | 0.0 | 45.0 | 55.0 | 100.0 |
| Total | | N | 30 | 305 | 348 | 683 |
| | | % | 4.4 | 44.7 | 51.0 | 100.0 |
| $\chi^2/p$ | | | 46.557/0.000 | | | |

people) are of the opinion that the number of speed bumps is high and the number of drivers who share this opinion is highest. It can be stated that the drivers in this group have negative opinions related with both of these speed enforcements. Of those who think that the frequency of speed bumps is sufficient, 55.1 (161 people) are of the opinion that the speed limits are sufficient as well. Of those who think that the speed limit enforcement is sufficient, 38.4 (112 people) are of the opinion that the number of speed bumps is high. This leads us to think that the drivers in this group have positive opinions for this application in comparison with speed bumps. However, based on the result of the chi-square test, there are statistically significant differences between the opinions of drivers related with the frequency of speed bumps and those related with speed limit enforcement via average speed cameras.

## 5. Conclusions

Average speed limit systems were applied without enforcement on eleven different sections in the Akdeniz University campus with speed limits of "20, 30, and 50 km/h" and they were found effective in decreasing the speeds of drivers. Comprehensive surveys were carried out in this study during the dates of 20.05.2013–24.05.2013 the results of which were then subject to statistical analyses. These surveys were related with "driver's personal characteristics, drivers' behavior, opinions on the speed limits enforced by average speed application in the campus, and other enforcement precautions" and were applied on the drivers in the campus. It was suggested that 52% of the drivers in the sample group of 729 drivers considered the speed limits enforced by the average speed cameras in the campus to be low. In addition, the chi-square test was carried out and the statistical significance of the chi-square value was considered in examining the relationship between four of the personal characteristics of the drivers who participated in the survey (gender, age, education level, responsibility level) and the 'opinions of drivers on speed limit enforcement'. A statistically significant difference was determined between the opinions of male and female drivers on speed enforcement application. This difference indicated that 60.8% of the male drivers and 39.2% of the female drivers were of the opinion that the speed limits applied were low. No statistically significant difference was determined between the opinions of drivers on speed enforcement applications in terms of age groups. A statistically significant difference was determined between the opinions of drivers on speed enforcement application in terms of education levels. It was found that 31% of the primary school graduates, 48.1% of college graduates, 52.5% of bachelor degree graduates, 65.6% of master's degree graduates, and 59.5% of doctorate degree graduates considered the applied speed limit to be low. This is an indication that there is a direct correlation between the education levels of the participants and their opinions that the applied speed limits are low. A statistically significant difference was determined between the opinions of drivers on speed enforcement application with regard to their responsibilities at the university. This difference is an indication that 62.5% of the academic staff, 50.3% of the administrative staff, and 51% of the students are of the opinion that the applied speed limits are low. It is thus an indication that a greater ratio of the drivers with academic duties is of the opinion that the speed limit values are lower than those for other drivers. Accordingly, it was thought that the speed

limits enforced by average speed enforcement were not considered reasonable by the drivers and that these limits might be neglected frequently in the future. It should be emphasized that the study area is a campus and the employed approach to adjusting speed limits must include the provision of the respect of drivers for speed limits, because the speed limits enforced in such areas should not involve the passivity of posing any risks to pedestrian and cyclist safety. The opinions on average speed enforcement of a total of 20 minibus taxi drivers driving regularly on R61 highway were examined during a study in South Africa. Interviews were conducted to determine the levels of understanding of these drivers with regard to the 100 km/h legal speed limit system that is in effect. When asked "whether they are aware of the legal speed limits or not", all drivers stated that they were aware of the speed limits. All drivers also proved their awareness of the matter when asked "whether they had been aware of the positions of average speed cameras located at the start and end points of the section". The drivers were asked "how they could be affected by the presence of the cameras" to which 80% responded that the presence of the cameras forced them to comply with the speed limits in proximity to the camera, while 20% stated that they were not affected in any way by the presence of the cameras because they generally do not comply with the speed limits. The drivers were then asked, "if they understood how average speed enforcement operates or not" to which only two out of twenty drivers (10%) responded as yes indicating that they know how the system operates. This study puts forth that a very small number of taxi drivers understand the concept of average speed enforcement and it was demonstrated by the authors that the drivers should be trained on how the system operated [50]. A survey of the perception of road users on speed perception was conducted on 2.977 drivers during a study carried out in Turkey by the general directorate of highways. It was observed that the majority of the survey participants complied with the traffic signs, traffic controllers, and signboards. Of the participants, 49% stated that they mostly complied with the traffic signs, traffic controllers, and signboards, while 43.3% indicated that they always complied. It was observed as a result of the survey data that 58.1% of the female participants and 42.6% of the male participants complied with speed related traffic signs, traffic controllers, and signboards at all times. Upon investigating the results, it was found that in terms of age, 60% of the participants in the age group of 65 and above indicated that they complied with the traffic signs, traffic controllers, and signboards at all times; 34.6% of those in the 18–24 age group and 37.8% of the participants in the 25–34 age group complied with traffic signs, traffic controllers, and signboards at all times. It was observed that positive behaviors related with compliance to traffic signs, traffic controllers, and signboards increased with advancing age. When asked, "Do you violate the speed limits?", 68% of the participants responded rarely, 18.5% never, 8.7% about half the time, 4.1% most of the time, and 0.7% always. After examining speed violation behaviors with regard to gender, it was detected that 33.1% of the female participants and 17.9% of the male participants indicated that they never violated the speed limits. Accordingly, females violate the speed limits less frequently than males as found by the results of the survey. A statistically significant difference was observed between gender and speed limit violation; hence, it can be concluded based on this finding that gender has an impact on speed limit violation. It was observed that the ratio of violating speed limits decreased with increasing age. A statistically significant difference was observed between age and speed limit violation [56].

Of the participants, 57.3% stated that they tend to overtake other vehicles (sometimes or always). A statistically significant difference was determined between the tendencies of drivers to overtake vehicles and gender. Results showed that males were more likely than females to overtake other vehicles ceteris paribus. This difference is a numeric indication that 40% of the male drivers and 48.1% of the female drivers did not tend to overtake other vehicles Similarly, 19.7% of the male drivers pointed out that they tended to overtake other vehicles, while only 11.1% of the female drivers tended to overtake other vehicles. A statistically significant difference was determined between the tendencies of drivers to overtake vehicles and age. This difference is a numerical indication that 17.4% of the drivers aged 30 and below and 52.05% of the drivers aged above 30 do not tend to overtake other vehicles, which shows that the tendency to overtake other vehicles put forth by the drivers themselves is much lower for drivers aged above 30 than younger drivers. A statistically significant difference was determined between the tendencies of drivers to overtake vehicles and education level. This difference is a numerical indication that the drivers do not tend to overtake other vehicles with increasing education level for primary school graduates with 39.3%, college graduates with 40%, Bachelor's degree graduates with 43.3%, Master's degree graduates with 47.6%, and doctorate degree graduates with 51.5%. This is an indication that the tendency to overtake other vehicles decreases with drivers' higher education levels. A statistically significant difference was determined between the tendencies of drivers to overtake vehicles in terms of taking responsibility at the university. This difference numerically indicates that 51% of the academic staff, 37.6% of the administrative staff, and 25% of the students do not have a tendency to overtake

other vehicles, meaning that while university students have the highest tendency to overtake other vehicles, academic staff have the lowest tendency among others. These results lead us to think that speeding behavior may be considered to be acceptable by the majority of the drivers. There are numerical differences between the "opinions on the enforced speed limits" of drivers who have a tendency to overtake other vehicles and those who do not have such a tendency; chi-square test results showed that these differences were not statistically significant. In other words, the opinions of drivers on speed limit enforcement are not affected by whether they have a tendency to overtake other vehicles or not. In addition, 99.1% of the drivers have indicated that they are aware of their responsibility for the passengers' safety (sometimes or always), meaning that they give importance to the passengers' safety. As indicated above, the ratio of participants among 2.977 drivers included in the survey in Turkey carried out by the general directorate of highways who responded as always or most of the time to the question of "do you race with other vehicles?" was quite low (1.5%), while the ratio of drivers who indicated that they would never race with other vehicles was reported as 76.6%. Similarly, the ratio of participants who responded to the question of "do you overtake the vehicle in front of you in areas where overtaking is prohibited?" as 'generally' was determined to be 1.3%, while the ratio of those who indicated that they would never overtake vehicles in overtaking-prohibited areas was observed as 74.6%. This study only achieved survey results and did not carry out any statistical analysis [56].

The relationship between the opinions of Turkish drivers regarding speed enforcement applications and their accident histories was not examined sufficiently despite the fact that Turkey is among the countries with the highest rate of killed or serious injury accidents. Of the drivers, 38.6% had no accident, whereas 61.3% had experienced accidents. Based on the results of the chi-square test, there are no statistically significant differences between the opinions on speed limit enforcement via average speed cameras of drivers who had accidents and those who had no accident. This shows that the opinions of these drivers on speed limit enforcement are not affected by whether they have had any accidents or not. It is commonly stated in the literature that people personally affected by an accident or those who are in some way affiliated with individuals affected by an accident tend to have positive opinions on speed limit enforcement via average speed cameras. However, the results of this sample group indicated that 60.3% (178 people) who have had an accident were of the opinion that the speed limits were low [24]. A different result was obtained by a study conducted in Cameroon which evaluated the accident histories of the drivers. A survey including items related to risk perception, safe behavior, and personal accident history was applied to a road user sample group composed of 525 (379 males, 132 females, and 14 with no gender information). In terms of the relation of the number of past accidents, it was found that the individuals were involved in with their safe behaviors and road travel risks. The relations between the accidents with which the participants are directly involved and the risk perception and safe behaviour use were examined. First, the impacts of direct accident history (yes, no), number of accidents (one, two, and more than three) on risk perception, and safe behavior were evaluated. As a result, ANOVA (Analysis Of Variance) was employed and its results helped determine that the numbers of previous accidents of the participants were related to the safe driving behavior perception and risk perception. According to the Post Hoc tests, the drivers involved in three or more accidents act less risky than those involved in one, two, or three accidents. Similarly, it was also reported that the drivers involved in more than three accidents behaved less safely than those involved in only one or two accidents. It was observed that elderly participants were involved in a larger number of accidents; however, it was concluded that age did not correlate with the risk perception and safe behavior [57]. Another study carried out in Turkey employed regression analysis and examined the relationship between the refraining behavior of drivers from driving with their accident history. Their cohort population comprised 153 male and 138 female participants, adding up to a total of 291. The results revealed that there was a positive relationship between the refraining behaviors of drivers from driving and their accident histories (number of previous accidents involving injury/death) [58].

Of the drivers, 50% stated that the number of speed bumps in the campus was too large. Of those who stated that the speed limits were low, 62.2% (224 people, majority of the participants) were believed the number of speed bumps was also too large. This may imply that these drivers do not positively support both of these traffic enforcement applications. Of those who assumed the speed limits as sufficient, 55.1% (161 people, second place majority of the participants) held that the number of speed bumps was enough. However, these participants exhibited positive support for both traffic enforcement methods. Of those who thought that the speed limits were low, 35% (126 people, 3rd place majority of the participants) maintained that the number of speed bumps was sufficient. It can thus be stated that these participants support average speed enforcement as an alternative and they comprise about 32.8% of all the participants [55]. The British Social Attitudes Survey carried out by a study and it was found that 72% of the drivers subject to the survey supported the low speed limits applied in

their settlement areas via average speed enforcement. However, only 43% of the drivers preferred the speed bumps and it might be required to enforce low speed limits. These survey results are not backed up by a statistical analysis [45].

Road structure in Turkey suits speeding and various precautions are taken against over speeding in places with high pedestrian and cyclist activity such as playgrounds, schools, university campuses, sports, and residential areas. However, only the speeding behaviors of the drivers are examined when taking these precautions and the underlying reasons for the different speeding behaviors of drivers along with driver characteristics are not studied; besides, neither evaluations nor analyses are carried out according to driver opinions. As is the case in many developed countries, the objective of the traffic speed inspections carried out is to prevent traffic issues, thus ensuring traffic safety while decreasing traffic accidents along with the involved mortalities and injuries. However, reasonable solutions should be developed when speed enforcements are applied with speed limits by taking into consideration the personal characteristics of drivers as well as their opinions.

The limitations of this study can be listed as follows:

1. "Of the drivers who participated in the survey, 40.7% work as part of the academic staff, 22.2% as part of the administrative staff, and 14.4% as students. Students at the campus generally prefer public transportation since they do not have their own vehicles due to limited economical resources (they are not drivers). Therefore, the ratio of student drivers who participated in the survey is lower than the ratio of academic and administrative staff drivers;
2. Some of the driver students did not accept participating in the survey during a period of time;
3. The number of individuals aged 61 and above with vehicles inside the campus was lower than those in the lower age groups (people in this age group are in their retirement periods in Turkey)".

A stricter compliance to speed limits can be ensured with better communication and information strategies for the users of the sections along with enforcements following any violations. Speed limit systems are not effective when there are no sufficient enforcements or the level of enforcements is not high enough. The impact of average speed enforcement on vehicle speeds was evaluated during a previous study for a three-lane highway in Belgium with two sections and a speed limit of 120 km/h as a result of which positive results were acquired with regard to speeding drivers. However, the authors indicated the importance of the implementation strategy and put forth that a better communication and information strategy with the road users along with higher enforcement levels related with the monitoring of violations may be beneficial for obtaining higher compliance to speed limits [52].

This study also shows that a speed limit enforcement system that is temporarily set up for testing purposes should be evaluated within the scope of driver characteristics, behaviors, and opinions. This study is also important as a model for similar institutions with campuses. In addition, the use of electronic speed signs is another method for ensuring that the "vehicle, cyclist, and pedestrian" traffic and their interaction inside the campus are safe. Electronic speed signs have become quite widespread in many spots in recent years and the most advanced of these can scan the license plate of the vehicles and display it along with their speed on the screen. The resulting embarrassment may act as a deterrent tool.

## 6. Discussion

As pointed out in the previous section, section control is a speed enforcement method that reduces the average speed of traffic. When considered from this point of view, an analysis was performed in this study regarding the perspectives on speed limits of drivers who display driving behavior on speed enforced sections in a campus. According to the survey and statistical analyses carried out, gender and education level are the factors that affect the opinions of drivers on the technology applied. Drivers with a negative opinion about this application are generally male and have a lower education level. The survey also includes a series of questions for evaluating the characteristics of the drivers as well as certain aspects of their opinions. For instance, the tendency of drivers to overtake other vehicles when driving is an indication that these drivers prefer speeding. Gender, age, education level, and employment level are the factors that affect driver behavior regardless of the enforcement technology used. These are mostly younger male drivers with lower education levels who do not have academic employment and who have a tendency to speed. After all these analyses, the speeding tendencies of the drivers corresponded to their opinions on speed limit enforcement. It was observed that the opinions of the drivers on speed limit enforcement were not affected by whether they had a tendency to speed or not. As indicated earlier, average speed enforcement as a method for reducing speed on low speed sections in Europe has provided an effective alternative in place of speed bumps, which is subject to many disadvantages. Indeed, according to the driver surveys and comparison of these two systems, the ratio of drivers in favor of speed bumps was lower. As a result of the survey and analyses carried out in

this study, campus drivers did not support any of the two traffic enforcement methods. This study provides an indication regarding the impacts of such systems on driver characteristics and opinions. Various data reflecting the opinions of drivers on their own speeding behaviors in comparison with other drivers as well as on the enforcement system were collected and analyzed in order to integrate issues that have been evaluated in parts in academic studies carried out in other countries, but have not been evaluated using statistical analyses. However, this study is only one example with regard to the opinions, analyses, and results of speed limit enforcement. Another purpose of this study was to indicate the necessity of evaluating the established systems from the perspective of the drivers in order to form a stronger foundation for planning and evaluating various road safety precautions and to better understand the relationship between traffic safety measures and driver speeds.

Even though initiatives for public education on traffic safety measures have increased worldwide, the positive and negative changes in the attitudes and opinions of the public may change dramatically among different countries. As a result of the literature survey carried out, a series of driver survey studies on drivers in the United Kingdom, France, Australia, Holland, and Italy indicated the relatively high driver acceptance levels with regard to average speed limit enforcement. However, related results generally do not include numerical data and the current literature that analyzes and evaluates these data is limited. Given that most drivers in Turkey have exhibited a low level of acceptance for average speed enforcement, it can be indicated that competent authorities should rationalize and acculturate the significance of these enforcement systems in order to increase the acceptance levels. It is important that the drivers understand the technology provided to them, because this will also help improve driver behavior and perspective. It can be indicated that there is a need for public education, especially for increasing the positive opinions on speed limit enforcement among drivers. Activities required for informing and raising awareness should be carried out in various channels such as newspaper, radio, television, social media, etc. in order to train the drivers on the necessity of adapting to average speed enforcement methods and speed limits. Based on the result of a study carried out in Australia, introducing modern traffic rules enforcement techniques such as average speed enforcement to the drivers and adapting a traffic safety culture are required for increasing the strength of such methods. It was considered that mass communication media and public education initiatives might result in significant positive changes in the attitudes of the public towards road safety. Significant successes have been attained in reducing the number of deaths in Australian highways; however, it is not clear just how much the Australian public appreciates these successes [59].

Moreover, similar situations can be followed on an international scale and comparisons can be made among the perspectives of drivers in different countries. In conclusion, the results of the current and previous studies point to the necessity of further studies that analyze driver opinions on speed limit enforcement applications used in different regions and different countries. The purpose of future studies should be to further improve the scientific rigor of evaluations that have been carried until today.

Traffic safety is generally expressed in terms of the officially recorded number of losses or accidents on the section. Many studies that have verified the positive relationship between high vehicle speeds and high risk of accident consider speeding as a major factor in the occurrence of traffic accidents. The number of studies is increasing which verifies the positive relationship between increased vehicle speeds and increased accident risk [14,17,29]. Therefore, speed management and speed limit measures were evaluated with regard to their sufficiency in reducing speed related deaths and injuries. Section control may theoretically provide safety measures because the risk and severity of an accident decrease when average speed and the change in speed decrease. Various academic studies have put forth the positive safety impacts of section control systems which have been evaluated positively with regard to their ability to reduce speed related deaths and injuries. However, such accidents at a university campus may be so rare as to not allow for any statistical analyses to be performed. Nevertheless, "motorized vehicle-pedestrian-cyclist" accident is a significant public health issue, especially on campus areas. Campuses with wide areas and high student population are generally dark spots for pedestrian accidents even though they are rich in many resources and opportunities and face unique difficulties when trying to deal with pedestrian-cyclist safety issues. The Akdeniz University campus has over 65.000 students and university employees. Such a highly unprotected population moves every day through fast traffic with motorized vehicles. Pedestrian and cyclist accidents may increase since many of them are willing to take the above risks. Even though speed limit applications may reduce driving speeds in such campuses, thereby leading to a decrease in accident risk and intensity, its effect will gradually decrease over time if it is not managed effectively and supported by proper enforcements. Moreover, speed limit applications alone will not be sufficient for such areas, leading to an increased need in applications related with designs for campus roads and pedestrian safety precautions. In addition, attitudes may change

over time about such applications and what was once accepted as 'normal' may be considered over time as 'illogical'. The following can be given as examples for such changes in attitude: it is possible for vehicle drivers to slow down before entering section control and, then, speed up after section control as they adapt to the installed system over time. In this case, there may be an increase in over speeding-related accidents after a certain controlled section. Furthermore, drivers who do not wish to pass through section control may prefer alternative routes over time. Thereby, accidents may take place in other areas (alternative routes) instead of locations with section control, which will have only changed the location of accidents (accident migration).

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## Biographies

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