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Impact on average vehicle speed with the introduction of educational actions and optical character recognition equipment in the Federal District, Brazil

Impacto sobre a velocidade média dos veículos com a introdução de ações educativas e equipamentos de leitura de placas no Distrito Federal, Brasil

Alan Ricardo da Silva[1], **Murilo de Melo Santos**[2]

[1]Universidade de Brasília, Distrito Federal – Brazil, alansilva@unb.br
[2]Departamento de Estradas de Rodagem do Distrito Federal, Distrito Federal – Brazil, murilomsantos10@gmail.com

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ABSTRACT
Every year, traffic accidents leave millions of people dead and injured worldwide. Speeding is one of the factors that most contribute to accident severity. The implementation of electronic road speed control equipment promotes a reduction in traffic accidents and their effects. Despite the effectiveness of those devices, some drivers have the habit of braking before and accelerating after checkpoints. A possible solution for the problem of that speeding-up effect and its consequences may be through controlling the average speed. The objective of this work is to verify the behavior of vehicle drivers regarding the average speed between control points when subjected to educational actions. For this, two educational actions were applied to sections of three highways of the Federal District, Brazil. The first action warned vehicle drivers that there was equipment on the highway for monitoring average speed between checkpoints and the second action was the sending of correspondence to vehicle owners who still traveled above the tolerated average speed, after the first educational action. The results of the second educational action indicated very little variation in the average speed when compared with the data of the first educational action.

RESUMO
Todos os anos, os acidentes de trânsito deixam milhões de pessoas mortas e feridas em todo o mundo. O excesso de velocidade é um dos fatores que mais contribuem para a gravidade dos acidentes. A implantação de equipamentos eletrônicos de controle de velocidade viária promove a redução dos acidentes de trânsito e seus efeitos. Apesar da eficácia desses dispositivos, alguns motoristas têm o hábito de frear antes e acelerar após os pontos de verificação. Uma possível solução para o problema desse efeito de aceleração e suas consequências pode ser por meio do controle da velocidade média. O objetivo deste trabalho é verificar o comportamento dos condutores de veículos quanto à velocidade média entre os pontos de controle quando submetidos a ações educativas. Para isso, duas ações educativas foram aplicadas em trechos de três rodovias do Distrito Federal. A primeira ação alertou os condutores de veículos que havia equipamentos na rodovia para monitoramento da velocidade média entre os postos de controle, e a segunda ação foi o envio de correspondência aos proprietários de veículos que ainda trafegassem acima da velocidade média tolerada, após a primeira ação educativa. Os resultados da segunda ação educativa indicaram muito pouca variação na velocidade média quando comparados com os dados da primeira ação educativa.

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1. INTRODUCTION

Every year around 1.2 million people die and millions of others are injured or incapacitated as result of crashes on public roads, especially in low and middle-income countries (WHO, 2008). According to Cannell and Gold (2001), traffic accidents in Latin America and the Caribbean account for somewhere in the region of thirty billion dollars in economic losses and one third of those are in Brazilian territory. Ferraz *et al.* (2012) consider that the high traffic accident rates constitute a veritable tragedy. Cause of accidents are varied and related to aspects of the vehicle, the roadway and the human element.

Speeding is one of the causes of accidents. The speed a vehicle is moving at is an important determinant in regard to injury; the faster the vehicle is travelling, the greater will be the energy inflicted on the occupants during a collision and the more serious the injury will be (Wilson *et al*., 2010). WHO (2009) has reported that excessive speed contributes to around 30% of traffic accidents in developed countries and 50% in developing ones. As an example, in New Zeeland, in 2002, the police attributed 126 deaths and 2,339 injuries to excessive vehicle speed. Those figures represented 31% of all the deaths and 17% of all the serious injuries in traffic accidents (Frith *et al.*, 2005).

In traffic accidents, lower speeds mean less serious injuries for the road users. That has been demonstrated by various research models and, outstandingly, by the Power Model proposed by Nilsson (OECD, 2018). According to that author, reducing speed by some km/h can cut down the risk of serious accidents and also benefit the quality of life especially in urban areas insofar as it means less air pollution, lower greenhouse gas emissions, less fuel consumption and less noise.

Electronic speed surveillance can be defined as the use of electronic means as one of the elements for controlling compliance with the speed limit rules for vehicular traffic (Gold, 2003). It is one of the means used to control the established limits and a valuable instrument for reducing the number and above all the severity of accidents. Speed control devices are implanted along the roadways to ensure the speed limits are kept to. Fixed radar devices are instruments for measuring the speed of vehicles at certain points.

The implantation of fixed radars along highways is an instrument for controlling the speed limit and, when it is adequately applied, leads to a reduction in traffic accidents, albeit sporadically. In a review study, Wilson *et al*. (2010) concluded that in the proximities of the camera installations reduction varied from 8% to 49% for all types of accidents but that most of the reviewed studies reported reduction in the range from 14% to 25%. All the 28 studies they reviewed reported identifying a lower accident rate in the vicinity of camera installations. The effectiveness of fixed radars as elements that contribute to a sporadic reduction of speed and of the accident rate of the localities where they are installed (Yamada, 2005) is undeniable.

However, even with the introduction of surveillance using fixed and mobile radars and the expressive results in accident reduction there is still the phenomenon whereby some drivers slow down before, and accelerate after passing the control point. According to the work of Oliveira et al. (2015), 200 meters after the cameras the vehicles had a significantly higher average speed and 38.1% of them were travelling at speeds above the limit. One way to change that risk-taking behavior on the part of drivers could be electronic control of the average speed between two points.

Control by sections is a relatively new measure that seems to be far more effective not only in reducing speeding but also in the achievement of a more homogeneous flow of traffic (OECD, 2018). Implanting Optical Character Recognition devices (OCRs) makes it possible to register the number plates of the passing vehicles. By registering the time that a given vehicle passes the control points it is possible to obtain the time it took to go from one radar to the next.

With the time known and the distance, it is easy to calculate the vehicle's average speed between the two points

Currently, in Brazil, average speed management cannot be enforced by fining offenders because the regulations associated to the respective legislation have not yet been established. Respecting the speed limit is in consonance with various proposed safety systems, especially the 'Sustainable Safety' system which seeks to ensure that drivers understand that the speed limit is actually the right speed to drive their vehicles at (Swov, 2007). Education is an essential instrument for developing individuals in society and in the case of traffic it becomes a key instrument for forming conscientious citizens better prepared for facing life and the traffic (Rodrigues et al., 2018). In that light, educational actions are the necessary tools for obtaining respect for the legal speed limit and they can produce significant results in managing average speed along stretches of highway.

In view of the above, this study sets out to verify the impact of educational actions on the average speed on stretches of highway in the Federal District, Brazil. More specifically, it seeks to analyze drivers' behavior in regard to average speed after a traffic education campaign and a notification sent to drivers' residences.

2. BACKGROUND

Intelligent Transport Systems (ITS) are valuable traffic management tools in the modern world and their use contributes to reducing accidents and enhancing the mobility of people and vehicles. All the services and activities associated with traffic operation and management are greatly facilitated by the integration of technologies designed to collect, store, transmit and analyze data (Bernardi, 2014). Intelligent Transport Systems can make their own contribution by improving traffic safety and for that reason they deserve a privileged status in the vision of Sustainable Safety (Wegman and Goldenbeld, 2006). This study addresses two of the technologies used in those systems: fixed radars and OCR.

2.1. Fixed radars and their traffic applications

All drivers choose the speed they travel at and the choice can impose risks that may affect the probability and the seriousness of their failures (Frith *et al.*, 2005). To minimize the effects of an inadequate choice, the traffic authority determines a speed limit for a given road section. However, some drivers insist on driving faster than the speed limit in force. According to Frith *et al.* (2005), excessive and inappropriate vehicle speed can be dealt with by surveillance. Effective surveillance is just as important as having the appropriate legislation in place because it acts in the sense of discouraging disobedience to the traffic laws and rules and in that way contributes to enhancing road safety (Ferraz *et al.*, 2012).

In Brazil, according to the provisions of Resolution 396, of the National Traffic Council (*Conselho Nacional de Trânsito* – CONTRAN), dated December 13, 2011 (Brasil, 2011), speed-measuring equipment and instruments (radars) are classified as fixed, static, mobile or portable.

Fixed radars are devices that use strips or sensors set in the road pavement to calculate vehicle speeds in each lane and photograph vehicles over the limit (Cannell and Gold, 2001). They are coupled to a fixed installation on purpose-built posts, or gantries and operate automatically, dispensing with the need for the presence of Traffic Inspectors (Yamada, 2005).

One of the problems associated to electronic radars is that some drivers tend to slow down when they are passing the camera only to speed up again when they are out of range of it (Oliveira *et al*., 2015). In a study conducted in the city of Belo Horizonte, those authors reported that although there are various studies that have shown how effective speed control by cameras is in reducing accidents in a zone of up to 200 meters after the cameras, their study revealed that after 200 meters beyond the speed cameras, only 60% of drivers were still driving within the limit. In that regard, Wilson *et al*. (2010) state that at a distance of one mile beyond their exposure to the radar, 78% of the vehicles were travelling at 5 miles an hour or more above the speed limit.

New strategies are needed to address that problem and curb the effect of speeding up again. One relatively new method that could potentially impede the phenomenon is to control the entire stretch of roadway and monitor the average speed over the stretch (Oliveira *et al*., 2015).

2.2. OCR Technology and its Traffic Applications

There are a variety of traffic management actions involving OCR including: detection of red-light violations at traffic signals; detection of the circulation of non-permitted vehicles in restricted areas or on restricted days; parking area management; and gathering trip origin and destination data. The use of automatic license plate readers to obtain the average speed for a highway section is a new application for OCR technology,

Automatic vehicle license plate recognition is a set of software and hardware resources that make it feasible to identify the passage of a vehicle, register an image of the vehicle and its license plate, and recognize the plate contents transforming them into characters that can be processed and transmitted remotely as is done with the image of the vehicle (Bernardi, 2014). At the moment the vehicle passes, the sensors focus on the license plate and capture an image that is recognized through the intermediation of purpose-developed computer programs.

The effect of speeding up again to excessive vehicle speed can be countered or minimized by controlling speed over entire sections or stretches of roadway. A relatively new method that could potentially impede the abovementioned effect is that of controlling the entire section of the roadway, that is, monitoring the average speed (Oliveira e*t al*., 2015). The procedure consists of the following: as the vehicle passes the first control point the respective license plate is recognized and registered together with the time of registration; when the vehicle passes the last control point of the section the procedure is repeated. With the information of the time spent and the distance travelled, the average speed (distance/time) can be calculated.

Several countries are already using this OCR technology, among them the United Kingdom (Cameron, 2008; Owen et al., 2016), Australia (Cameron, 2008), Italy (Autostrade Tech, 2019), Austria (Soole et al., 2013) and Belgium (Vanlommel et al., 2015). In Brazil automatic license plate reading is used in some cities like São Paulo and Brasília. Speeding control based on average speed measurement could be an effective tool for obtaining greater driver compliance with the speed limits established for road safety reasons. As mentioned above, it is already being practiced in several cities. Even though current Brazilian legislation does not permit fining offenders for violations based on average speed surveillance, the Office of the Federal Attorney General by means of its Technical Opinion nº. 00679/2017/CONJUR-MCID/CGU/AGU has validated an understanding whereby average speed surveillance can be used as part of road safety education interventions.

3. MODEL CALIBRATION

The purpose of the method described in Figure 1 below, is to verify driver behavior in road sections after the educational actions have been carried out warning them that average speed is being monitored by the traffic authorities. In this study, data analysis made use of SAS 9.4 software.

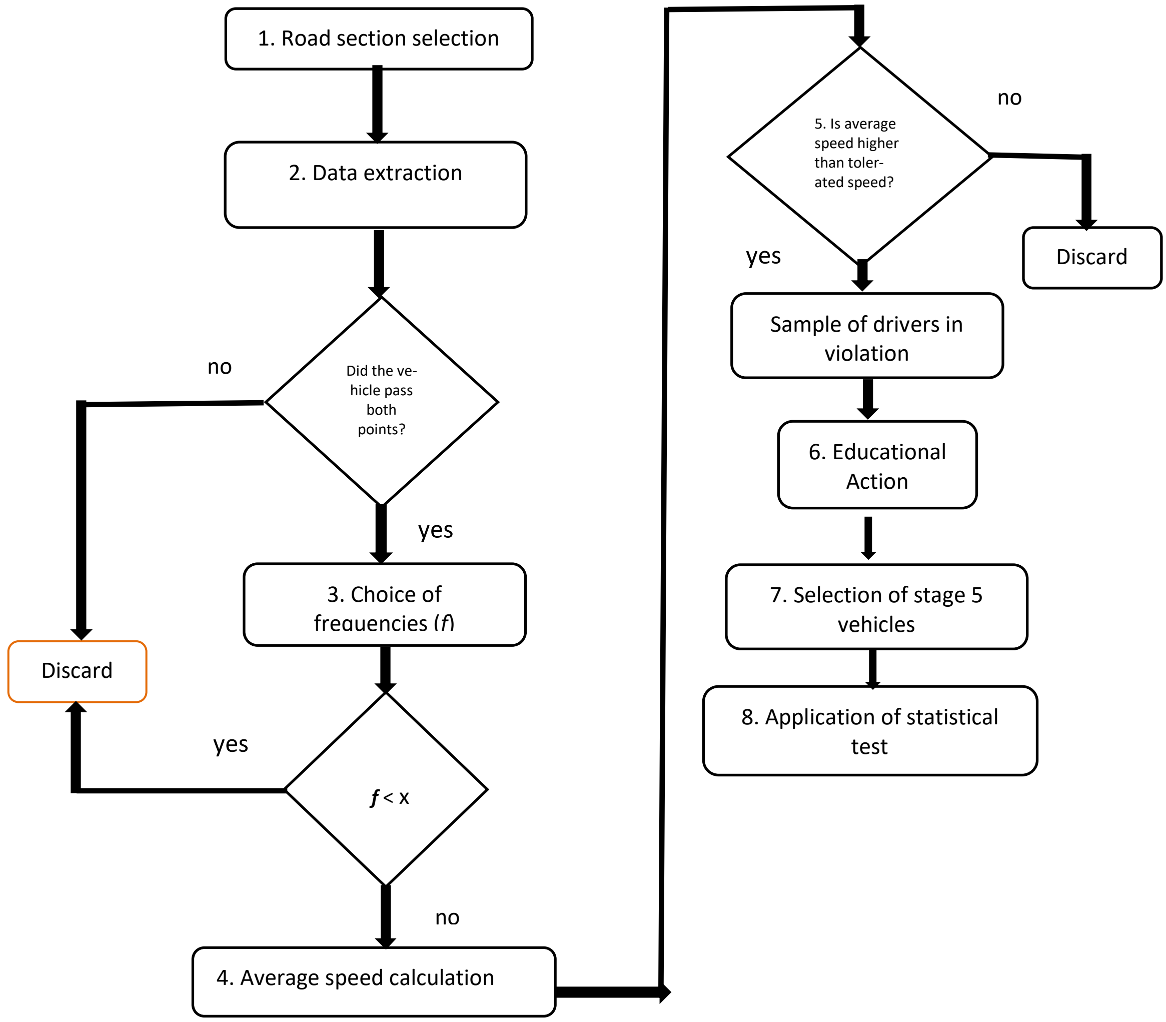

Figure 1. Methodological Flow Diagram

3.1. Stage 1: Road Section Selection

The proposed method was applied in the city of Brasília where three highways were selected (Figure 2): DF-002, DF-009 and DF-095. The first is 13 km long and has three lanes in each direction separated by a median strip. The legal speed limit is 80 km/h. The second road crosses a residential neighborhood known as Lago Norte and is 10.7 km long. The speed limit is set as 60 km/h. The third roadway is a highway connecting the cities of Taguatinga and Ceilândia to Brasília. The legal speed limit is 80 km/h.

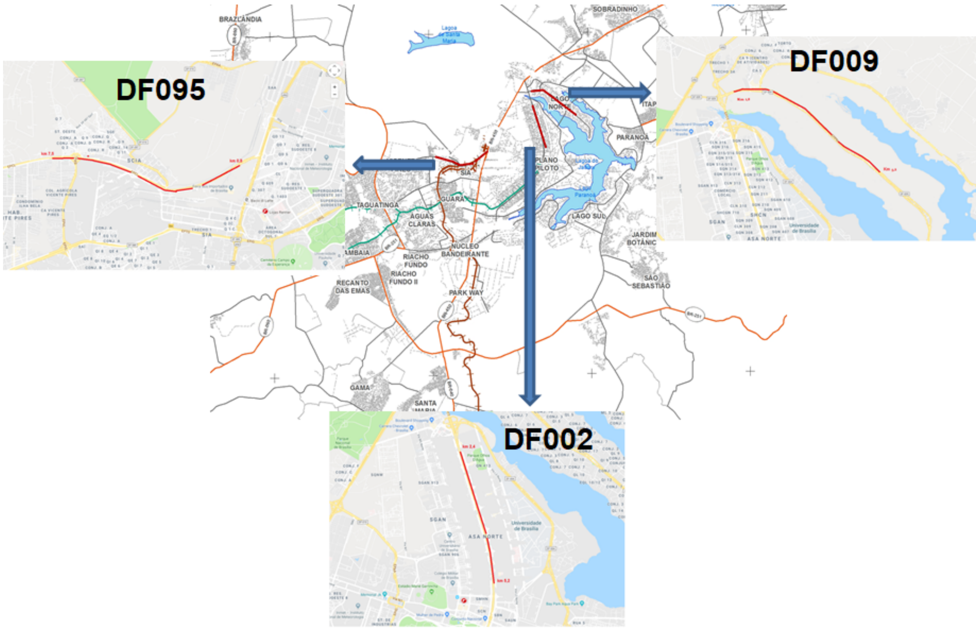

Figure 2. Highways selected for this study.

3.2. Stage 2: Data extraction

The research established three timeframes: a pre-educational period, the period of the first educational action and the period of the second educational action. During each period traffic volume data was obtained on a daily basis from the OCR during two successive weeks. Figure 3 shows the sequence of the periods of data collection.

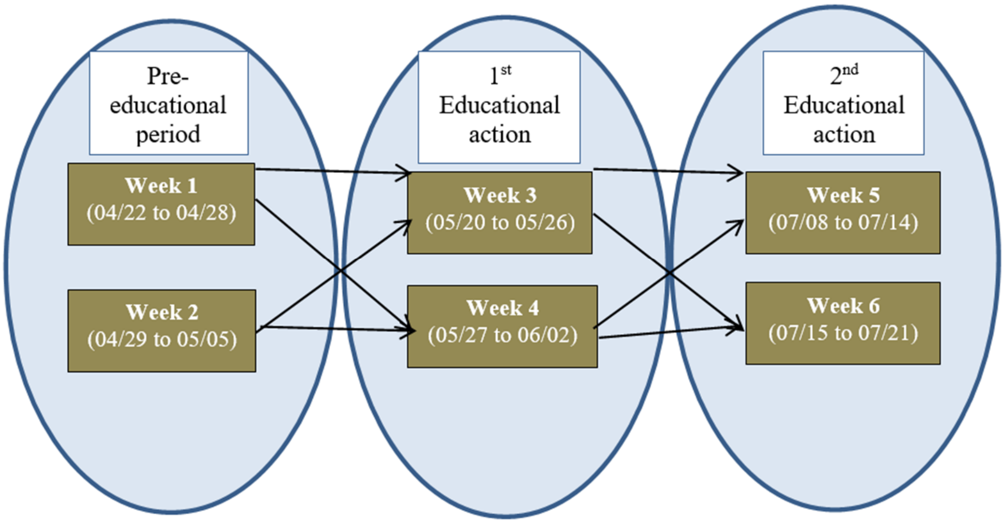

Figure 3. Schematic representation of the data collecting periods

A pre-educational period was established to verify whether there were any variations in average speed prior to unfolding any educational activity so that it would be possible to conclude, after the activity had been carried out, whether or not any eventual reduction in average speed had to do with the action. The two weeks (Weeks 1 and 2) prior to the beginning of the planned educational action were selected for that purpose. It was expected that there would be no differences among the average speeds between the weeks of measurement in the pre-educational period.

Table 1 and Table 2 show the number of vehicles that passed both points on the highway and the numbers of vehicles that were registered 4 times or more and their respective percentages for each of the highway sections studied during, respectively, week 1 and week 2

Table 1 – Number of vehicles passing both control points of the highway and passing 4 times during Week 1 (04/22/2019 to 04/28/2019)

	Highway	Small hrs.	Morning	Afternoon	Night	Total
		Period				
VEHICLES PASSING BOTH CONTROL POINTS	DF-002	852 (1.39%)	18,886 (30.74%)	32,118 (52.28%)	9,579 (15.59%)	61,435 (100%)
	DF-009	304 (1.18%)	8,705 (33.84%)	14,323 (55.68%)	2,390 (9.29%)	25,722 (100%)
	DF-095	3,275 (5.84%)	24,357 (43.42%)	24,197 (43.13%)	4,270 (7.61%)	56,099 (100%)
	Total	6,692	95,228	113,940	26,855	242,715
VEHICLES PASSING 4 TIMES	DF-002	8 (0.87%)	362 (39.52%)	496 (54.15%)	50 (5.46%)	916 (100%)
	DF-009	0 (0.00%)	241 (32.74%)	484 (65.76%)	11 (1.49%)	736 (100%)
	DF-095	105 (15.96%)	382 (58.05%)	161 (24.47%)	10 (1.52%)	658 (100%)
	Total	143	2,692	1,937	123	4,895

Table 2 – Number of vehicles passing both control points of the highway and passing 4 times during Week 2 (04/29/2019 to 05/05/2019)

	Highway	Small hrs.	Morning	Afternoon	Night	Total
		Period				
VEHICLES PASSING BOTH CONTROL POINTS	DF-002	913 (2,18%)	11.983 (28,58%)	22.868 (54,53%)	6.170 (14,71%)	41.934 (100%)
	DF-009	270 (1,05%)	9.225 (35,96%)	14.270 (55,63%)	1.885 (7,35%)	25.650 (100%)
	DF-095	2.990 (5,65%)	26.594 (50,21%)	19.468 (36,75%)	3.915 (7,39%)	52.967 (100%)
	Total	6.820	89.170	92.895	23.942	212.827
VEHICLES PASSING 4 TIMES	DF-002	4 (3,2%)	18 (14,40%)	92 (73,60%)	11 (8,80%)	125 (100%)
	DF-009	0 (0,00%)	200 (33,67%)	389 (65,49%)	5 (0,84%)	594 (100%)
	DF-095	48 (11,54%)	295 (70,91%)	63 (15,14%)	10 (2,4%)	416 (100%)
	Total	67	1.418	882	65	2.432

One feature that stands out in the analysis of the numbers of vehicles passing the two points, in all the highway sections, is the considerable drop compared to the numbers passing each single point. For example, in the case of DF-095, week 1, the single point / two points ratio is 3.21:1. One of the reasons for that is the presence of various lateral access roads in all the highway sections analyzed.

3.3. Stage 3: Choice of Frequency

The next step was to define the frequency with which the vehicles travel on the sections being analyzed. This work seeks to evaluate the behavior of drivers using the highway more frequently and those accustomed to indulge in speeding. As the frequency goes up, the number of vehicles to be analyzed goes down, therefore it was necessary to find a frequency that would correspond to a number of drivers large enough to enable the study to proceed. On the basis of the data analysis a frequency of 4 times for a vehicle to have passed the control points during weeks 1 and 2. That was because a frequency of 5 would have meant very few vehicles registered and a frequency of 3 might have made it difficult to find those same vehicles at a later date thus making this paired samples-type study unfeasible. The selected frequency of 4 provided significant data for the study. Thus those vehicles that passed fewer than 4 times in a section in a given week were discarded. We can see these data in Tables 1 and 2.

The most notable feature here is the high percentage (15.96%) of vehicles passing 4 times or more during the small hours after midnight in the stretch of the DF-095 highway; far higher than the values observed for the other sections. Another unexpected fact was the high percentage of vehicles passing in the afternoon period (65.76% of the registration) on the DF-009 highway, because the direction of traffic flow there is from the neighborhoods to the center. It was expected that the highest volume of traffic in that direction would have been in the morning period.

3.4. Stage 4: Average speed calculation

As mentioned previously, with the registrations of the vehicles that passed both control points at least 4 times during the period it was possible to calculate the average speed of each passage through the sections.

At that stage it was observed that some of the average speeds were very low. That may have been for several reasons such as traffic jams, accidents, vehicle breakdowns and others. Given that none of those aspects are of interest to this study, such low speeds were discarded (low speed was taken to be half the speed limit for the section). Thus, we understand that the traffic conditions were comparable because they were measure at the same weekday, hour and with difference of one month between them, with the same traffic conditions, i.e, no constructions or roadblock in traffic, and therefore, there is no effect of flow on speed. The profiles per speed range of the percentages obtained for each highways section for weeks 1 and 2 are very similar confirming a pattern of conformity.

3.5. Stage 5: Comparison of speeds

In Brazil, to constitute a punishable violation for speeding, the speed measured by the respective instrument or equipment must be higher than the sum of the speed limit in force and the maximum error allowed for by the metrological legislation in force. In that light, the study considered excessive speed to be any speed value equal to, or higher than 68 km/h and 88 km/h for the highways in this study with limits of 60 and 80 km/h respectively.

Thus based on the values obtained with calculations made in Stage 4 a selection was made of those vehicles with average speeds higher than: 68 km/h for the DF-009 highway and 88 km/h for the DF-002 and DF-095 highways. The numbers of vehicles identified as having overstepped the speed limit in Week 1 and Week 2 are displayed in Table 3.

Table 3 – Number of vehicles passing over the considered speed limit in Week 1 (04/22/2019 to 04/28/2019) and Week 2 (04/29/2019 to 05/05/2019)

		Period				
	Highway	Small hrs.	Morning	Afternoon	Night	Total
Week 1	DF-002	0	179	131	3	313
		0.00%	57.19%	41.85%	0.96%	(100%)
	DF-009	3	79	77	14	173
		0.00%	32.74%	65.76%	1.49%	(100%)
	DF-095	**67**	172	247	12	498
		13.45%	34.54%	49.60%	2.41%	(100%)
	Total	73	579	542	32	1226
Week 2	DF-002	1	9	33	0	43
		2.33%	20.93%	76.74%	0.00%	(100%)
	DF-009	0	60	78	11	149
		0.00%	40.27%	52.35%	7.38%	(100%)
	DF-095	**26**	87	69	15	197
		13.20%	44.16%	35.03%	7.61%	(100%)
	Total	31	198	222	30	481

Outstanding features here are the high percentage (13.45%) of vehicles travelling at or over the limit considered by the study (88 km/h) in the section of the DF-095 as compared to the other highway sections. As was the case in Week 1 there was a high percentage (13.02%) of vehicles speeding during the hours after midnight on the section of the DF-095 in Week 2 compared with the sections of the other two highways.

3.6. Stage 6: Educational actions

Arousing driver awareness to obtain a more adequate behavior is one of the objectives of traffic-related educational actions. This study unfolded two educational actions aimed at reducing the average speeds of drivers who habitually drive at excessive speeds. The actions are described below.

3.6.1. First educational action

The first educational action consisted of informing highway users in the Federal District that the roadway was equipped with devices for registering average speeds between electronic check points. Previously the population had only been aware that there was equipment installed in certain places (fixed radars) that measured speed at those points.

On May 10, 2019 the Brasilia government news agency made an announcement informing people about the beginning of an educational initiative on Federal District highways.

From then on various electronic sites in the region replicated the news giving the event wide publicity. Radio and television news programs also broadcast news of the event. The announcement of the new surveillance system gave rise to a considerable polemic especially in the social media. The polemical nature of the topic actually helped to give the action even greater media coverage. However, this study did not investigate whether all the road users were aware of this new way of measuring speed.

One of the educational actions consisted of installing luminous panels displaying messages in the sections of the highways that were to be studied (the DF-002, DF-009 and DF-095 highways). Two messages were displayed alerting those passing by to: 'AVERAGE SPEED SURVEILLANCE' and 'YELLOW MAY', a commemorative month in Brazil in favor of less accidents. The messages were displayed 24 hours a day for 25 successive days (May 10 to June 4 2019) when they were removed. There were two panels for each road section one prior to the first control point and another half way along the section.

Data gathering associated to the first educational action began 10 days after the first announcement of the average speed surveillance intention. During those ten days the action was widely publicized in radio and television news programs as well as in other electronic media. The periods analyzed were from 05/20/2019 to 05/26/2019 (Week 3) and from 05/27/2019 to 06/02/2019 (Week 4).

3.6.2. The second educational action

This action consisted of sending letters to those drivers who, in spite of the information about the first educational action, had nevertheless persisted in driving at excessive speed (over 68 km/h on the highway where the limit was 60 km/h and over 88 km/h on those where the limit was 80 km/h). The first letters were sent out on 06/27/2019 and the last ones on 07/05/2019. Data gathering for analysis took place from 07/08/2019 to 07/14/2019 (Week 5) and from 07/15/2019 to 07/21/2019 (Week 6).

The number of letters sent out was based on a random sampling of those drivers who had driven over the limits as set out in the preceding paragraph. The letters were sent through the post, each with a tracking code so that its trajectory could be accompanied. Some of the letters were returned for a variety of reasons and the corresponding vehicles were eliminated from the sample for comparison. It was not possible to ascertain whether the driver in question received the correspondence because the registered address is always that of the vehicle's proprietor.

3.7. Stage 7: Selection of the vehicles from stage 5

With the data gathered "before" the vehicles for Stage 5 were selected to form a second database with the "after" registrations. In that process some of the vehicles registered "before" did not appear in the "after" database. In this case, it is only accounted those vehicles that have exceed the speed limit in "before" period and were registered in the "after" period. Consequently only those vehicles registered both "before" and "after" the educational event were considered.

3..8 Stage 8: Statistical testing

The paired-t test is appropriate for comparing two sets of quantitative data that are effectively paired and the null hypothesis is that the average difference between the paired observations is zero (Zar, 2010). With the average speed of each vehicle before and after in hand, the difference between it and the (considered) speed limit is calculated "before" and "after" the educational action. When this difference cannot be assumed to have a normal distribution then the most powerful test to apply is the Wilcoxon test (Blair and Higgins, 1985).

First it was necessary to discover whether there are any significant differences between the average speeds for the two weeks selected during the pre-educational period. Contrary to expectations, there was indeed a significant alteration from Week 1 to Week 2 insofar as there was significant drop in average speed in Week 2. That means that Week 2 should be considered critical and more robust for analysis purposes as it was the one that obtained the lowest average speed values and, furthermore, it was closer in time to the period of evaluation (Weeks 3 and 4).

Table 4 shows the comparative data for the weeks prior to the educational action (Weeks 1 and 2) and the weeks subsequent to the educational action (Weeks 3 and 4).

Table 4 – Summary of the comparative statistical analyses of data gathered prior to and subsequent to the first educational action

Highway	Period		Sample	$\overline{D}$	S_D	Paired test	Reject H_0?
	Before	After	*n*			(p-value)	
DF-002	Week 1	Week 3	118	- 5.2750	0.5916	-8.91701 (< 0.0001)	Reject
		Week 4	142	-5.5740	5.7214	-11.6095 (< 0.0001)	Reject
	Week 2	Week 3	22	-5.4032	5.6227	-4.50738 (0.0001)	Reject
		Week 4	25	-4.0720	3.7322	-5.45526 (< 0.0001)	Reject
DF-009	Week 1	Week 3	40	-13.0121	9.3563	-8.91701 (< 0.0001)	Reject
		Week 4	48	-11.9138	6.9468	-11.8819 (< 0.0001)	Reject
	Week 2	Week 3	51	- 10.5086	6.5602	-11.4396 (< 0.0001)	Reject
		Week 4	41	-12.2162	6.2081	-12.5999 (< 0001)	Reject
DF-095	Week 1	Week 3	189	-3.5365	6.5041	-7.47512 (< 0.0001)	Reject
		Week 4	167	-3.4348	6.5101	-6.81818 (< 0.0001)	Reject
	Week 2	Week 3	88	-3.2339	5.8170	-5.21509 (< 0.0001)	Reject
		Week 4	71	-3.4656	6.3762	-4.57986 (< 0.0001)	Reject

Criterion for Reject H_0? decision: No, if p-value >0.05, otherwise, reject.

The average values for the differences in average speed of the vehicles were all negative. They were greater, however, for the DF-009 highway section and lowest for the DF-095. In regard to the statistical analysis, the DF-095 obtained the highest values (in modules) on average. Based on the two parameters it can be inferred that, in spite of DF-009's official speed limit's being lower than the others (60 km/h), the educational action was more efficacious there. However it cannot be said that the action was less efficacious for the DF-095 highway because the statistical test presented lower values than it did for the other road stretches even though the values obtained for the average differences were lower among the analyzed sections.

Kolmogorov-Smirnov test for normality was applied, resulting in p-values greater than 5%, for all the tests and therefore not rejecting the null hypothesis. Accordingly, with a level of confidence of 95% it can be stated that the distribution of the data is normal and therefore the paired t-test results are validated.

The next step was to unfold the second educational action as described in Section 3.6.2. With the Week 2 data in hand regarding the vehicles that passed the control points at least 4 times in the respective periods over the considered speed limit and that persisted in that behavior in Weeks 3 and 4, a sample selection was made and correspondence was sent to the owners of the respective vehicles informing them of their irregular driving behavior and the harmful effects associated to it. Summaries of the comparative results are displayed in Tables 5 and 6.

Table 5 – Summary of the comparative statistical analyses of data gathered before and after the second educational action involving notification of drivers in the Week 2 (04/29/2019 to 05/05/2019)

Highway	Period		Sample	$\overline{D}$	S_D	Paired test	Reject H_o?
	Before	After	n			(p-value)	
DF-002	Week 3	Week 5	15	-6.6850	3.7239	-6.95264 (< 0.0001)	Reject
		Week 6	6	-11.6529	6.5350	-4.36781* (0.0036)	Reject
	Week 4	Week 5	48	-2.6410	7.9645	-2.29735 (0.0130)	Reject
		Week 6	5	-5.6857	2.9624	-4.29170* (0.0063)	Reject
DF-009	Week 3	Week 5	9	-13.1635	7.7752	-5.079* (0.0005)	Reject
		Week 6	8	-11.1510	4.1355	-7.62656* (< 0.0001)	Reject
	Week 4	Week 5	3	-7.1789	13.0357	-0.95386* (0.2204)	No
		Week 6	4	-0.5517	5.8454	-0.18876* (0.4311)	No
DF-095	Week 3	Week 5	8	-6.6948	8.2240	-2.3025* (0.0274)	Reject
		Week 6	5	-9.2399	4.0619	-5.08658 (0.0035)	Reject
	Week 4	Week 5	4	-0.2294	4.1769	-0.10983* (0.4597)	No
		Week 6	1	-6.2248	-	-* -	-

Criterion for Reject H_o? decision: No if p-value >0.05, otherwise, reject.
(*) the student's- t test should not be considered

Thus, as mentioned previously, given that the data did not obey a normal distribution a new table was elaborated after applying the Wilcoxon tests. Table 6 displays the values obtained after applying the Wilcoxon to data obtained prior to and after the second educational actions involving drivers identified in the Week 2 database.

Table 6 – Summary of the modified statistical analyses (Wilcoxon test) of data with a non-normal distribution gathered before and after the second educational action (notification of drivers identified in the Week 2 database)

Highway	Period Before	Period After	Sample n	$\overline{D}$	S_D	Wilcoxon test (p-value)	Reject H_0?
DF-002	Week 3	Week 6	6	-11.6529	6.5350	-10.5 (0.0156)	Reject
	Week 4	Week 6	5	-5.6857	2.9624	-7.5 (0.0312)	Reject
DF-009	Week 3	Week 5	9	-13.1635	7.7752	-22.5 (0.0019)	Reject
		Week 6	8	-11.1510	4.1355	-18 (0.0039)	Reject
	Week 4	Week 5	3	-7.1789	13.0357	-2 (0.0250)	No
		Week 6	4	-0.5517	5.8454	-1 0.4375	No
DF-095	Week 3	Week 5	8	-6.6948	8.2240	-14 (0.0273)	Reject
	Week 4	Week 5	4	-0.2294	4.1769	0 (0.5000)	No
		Week 6	1	-6.2248	-	-0.5 (0.5000)	No

Criterion for Reject H_0? decision: No if p-value >0.05, otherwise, reject.

In a similar way for the sample group obtained in Week 1 (not shown here because the space), the samples from Week 2 on the section of the DF-002 highway showed a rejection of the null hypothesis, that is to say, for a significance level of 5% the hypothesis that there would be no variation in the average speed was rejected. However, for the stretches of the other two highways, the DF-009 e DF-095, the results were far less decisive; two samples resulted in rejection of the null hypothesis and two in the non-rejection of it.

In all sections in study the reductions in average speed obtained were very small (2.64 km/h, 7.18 km/h and 0.23 km/h for the Highways DF-002, DF-009 and DF-095, respectively). That was a determinant factor for the low values registered by the statistical tests for these samples.

Another analysis involved a comparison of the average speeds of those vehicle proprietors who received a notification and those who did not. In this case the two samples are considered to be independent (in the preceding examples the samples were paired). Accordingly, the statistical test applied was the Wilcoxon's non-parametric *U*, more appropriate for independent samples. All tests for all three roads and all weeks did not reject the null hypothesis (that there would be no alteration in the average speed). All 24 tests carried out among vehicle owners both with those that received correspondence and those that did not received correspondence, rejected the null hypothesis which was that the average speed of those receiving correspondence and those not receiving it would be the same. It can be seen however, that the values obtained were low, indicating little variability in the average velocity between vehicle owners who received a notification letter and those who did not.

The test result showed that there was no significant alteration in the average speed after the vehicle owners had received a warning that the speed limits had been violated in the stretches of highway in analysis. That may have been because there was no punishment associated to the warning and the correspondence explicitly stated that no penalties for the driver were involved and that the communication was merely educational. Furthermore it was difficult to know whether the correspondence reached the actual driver given that the license plates are registered in the name of the owner and it is the owner's address that is registered in the Traffic Department of the Federal District, so the vehicle may have been driven by a different person at the time of the registrations. That too may have had an influence on the unexpected result.

4. CONCLUDING REMARKS

Excessive speed of vehicles on roads and highways is one of the main factors involved in automobile accidents. Various countries have endeavored to avoid that inappropriate behavior by educational and/or punitive interventions. Electronic surveillance is one of the mechanisms that have been implanted in many cities and highways and it has achieved satisfactory results. However, in Brazil, one of the problems hampering the implantation of control based on average speed is the absence of the necessary regulations to enable the application of sanctions for excesses. Road safety education is another tool that can be used to obtain a change of inadequate behavior on the part of drivers.

This study sought to assess the impact of average speed control on drivers using certain stretches of highways applying "before" and "after" methodology associated to educational actions. With the unfolding of two successive educational actions, it was possible to make comparisons and verify the impact of implementing devices that permit speed control based on average speed measurements.

It was found that a considerable number of drivers insist on driving at speeds above the limit between the control points in the stretches of roadway considered by this study. In the two periods analyzed it was found that prior to the first educational action 21% of drivers travelled at an average speed higher than speed limit of 60 km/h on the DF-009 highway. On the DF-095, 40% of the drivers traveled at speeds over the 80 km/h limit and also on the DF-002, 28% of them traveled at speeds above the 80 km/h limit. That evidence is even more worrying when one considers that between the control points analyzed in this study there are speed reducing devices, namely fixed radars and traffic lights. The concern here is that those vehicles must have momentarily hit very high speeds at some point in the intermediate stretches of roadway.

The statistical analysis reveals the efficacy of the first educational action on the three highway stretches that were analyzed. All the results of the paired tests significantly rejected the null hypothesis that there would be no variation in the average speed. The "before" and "after" comparison revealed a reduction in the average speed to a value below the established speed limit. The reduction varied from 41% (section of the DF-095 – Week 1 compared to Week 3) and 94% (section of the DF-009 – Week 1 compared to Week 3), when the entire sample was analyzed.

Lastly, given that the aim was to verify the efficacy of sending correspondence to drivers regarding excessive speed, statistical tests were carried out with the proprietors of vehicles who received such correspondence informing them that they were in violation of the traffic laws (driving faster than the speed limit in a given section) and those who did not receive correspondence. The tests revealed little variation in speed between the independent samples thereby not rejecting the hypothesis that there was no highly significant variation in speed. That means that the second educational action failed to obtain the expected result. However, this issue could be related to the small sample size, and for future studies, we recommend increase the period of data extraction (Stage 2 at section 3.2) from one week to two or three weeks, in order to have more drivers to be analyzed.

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