Evaluation of Transverse Thermoplastic Pavement Markings for Speed Reduction in Costa Rica

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Abstract

In an effort to reduce vehicle speeds in highway sections of the national road network, LanammeUCR at the University of Costa Rica is coordinating research on low-cost road safety infrastructure countermeasures. In 2010-2011, the performance of transverse pavement markings in Canada had been studied as a speed-reduction countermeasure for intersections in the City of Fredericton, New Brunswick. The evaluation of transverse pavement markings in Costa Rica was based on the experience and results of the project undertaken in Canada.

Transverse pavement markings were proposed at three specific locations in Costa Rica's central metropolitan area, including two different marking designs. The purpose of the markings at two urban highway locations was to create such an effect on drivers that will give them the feeling of driving faster as going through the speed zone encouraging drivers to reduce their speeds. A second pattern was designed to alert drivers of an upcoming school zone in a rural mountainous two-lane highway. The use of double-layered thermoplastic material added a noticeable vibration effect, mainly for passenger vehicles.

A before-and-after statistical study was proposed to measure the effectiveness of the markings based on speed data collected using a digital speed radar. Results distinguished between the two patterns at the three study road sections, and the lasting effect over time. Based on statistical analyses, average speed reductions were more noticeable at the end of the speed zone and downstream at the three sites, achieving speed reductions of up to 18%, similar to the findings in the project in Fredericton. Operating speed reductions ranged 2-17% in all three sites. In terms of the effect over time, there is no evidence of a novelty effect during the first 6 months after the installation of the markings. A similar effect was observed at the intersections in Fredericton.

Résumé

Dans un effort pour réduire la vitesse des véhicules dans des sections de route du réseau routier national, le LanammeUCR de l'Université de Costa Rica développe des projets de recherche pour tester des mesures de sécurité routière à bas coût pour améliorer l'infrastructure routière. En 2010-2011, l'efficacité des marquages routiers transversaux avait été évaluée au Canada, comme une intervention visant à réduire la vitesse dans quelques intersections de la ville de Fredericton, au Nouveau-Brunswick. L'expérience et les résultats de ce projet-là au Canada ont servi de base pour la conception et l'évaluation des marquages routiers transversaux au Costa Rica.

Des marquages routiers transversaux ont été proposés à trois endroits spécifiques dans la zone centrale du Costa Rica, en utilisant deux modèles différents de marquage. Le but de ces marquages transversaux espacés à des intervalles progressivement décroissants dans une autoroute urbaine était de donner aux conducteurs la sensation d'accélération, et donc, les encourager à ralentir. Un deuxième modèle a été conçu pour alerter les conducteurs d'une zone scolaire à proximité dans une route rurale à terrain montagneux. Les marquages ont été installés à double couche en matériel thermoplastique pour amplifier le bruit de roulement, surtout pour les véhicules légers.

Une analyse statistique de type « avant-après » a été adoptée pour mesurer l'efficacité des marquages routiers transversaux, à partir des données recueillies à l'aide d'un pistolet radar de contrôle routier. Les deux modèles ont été évalués dans les trois sections d'étude, y compris l'effet durable dans le temps. À partir des analyses statistiques, des réductions de la vitesse moyenne étaient plus perceptibles dans les trois sites vers la fin de la zone marquée et après cette zone, de l'ordre de 18% (soient des réductions similaires aux résultats du projet à Fredericton). Des réductions de la vitesse opérationnelle de l'ordre de 2 à 17% ont été obtenues dans les trois sites. Par rapport à l'effet dans le temps, il n'y a aucune preuve d'un effet de nouveauté durant les 6 premiers mois après l'installation des marquages, et un comportement similaire avait été observé à Fredericton.

INTRODUCTION

Speeding is a major worldwide problem causing fatalities and severe injuries every year, although in low and middle-income countries the situation tends to worsen when compared with statistics of high-income countries. For instance, data from the Pan American Health Organization (PAHO/WHO, 2009) report a rate of 8.8 road traffic deaths per 100,000 population in Canada, whereas in Costa Rica it shows 15.4 deaths per 100,000 population (both for the period 2006-2007), just below the regional average for the American continent of 15.8 deaths. Rates in the Americas go as high as 22 deaths per 100,000 population. Data from Transport Canada show even a lower rate for the year 2009, close to 6.5 deaths per 100,000 population (WHO, 2013), a very positive trend towards fewer road traffic fatalities.

In a middle-income country such as Costa Rica, road infrastructure failures increase the risk of high severity road crashes. Insufficient enforcement and road safety education also play an important role in our driving culture and road accident historical trends. In terms of infrastructure, a significant number of roads in Costa Rica do not have an adequate balance between their design speed and the posted speed limit, which considerably affects the real operating speed at which drivers feel comfortable, in a particular facility. This has urged the authorities to enhance road safety through a multidisciplinary approach. Among several countermeasures and new policies, a Road Safety Manual was proposed, in order to incorporate systematically road safety standards and best practices in all new construction and existing road infrastructure. LanammeUCR at the University of Costa Rica is currently developing this manual. Low-cost road safety countermeasures will have a prevailing role in the manual, and to accomplish this, LanammeUCR is coordinating research projects in various road safety infrastructure topics.

Peripheral and transverse markings are very well-known countermeasures among road safety and transportation engineers, and they have been tried in different countries mainly since the 1980's. Back then, marking schemes were designed to create a visual effect for drivers to reduce their speeds. Marking patterns have been very diverse, as well as the results after the implementation. As discussed by Allpress and Leland in their publication about obtrusive perceptual countermeasures, Rutley had previously stated a hypothesis since 1975, that *"if decreasingly spaced transverse lines are placed on the road, motorists will perceive themselves to be accelerating and will compensate by slowing"* [1]. The use and effects of these markings have been documented by several authors, and their main uses include horizontal curves, school zones, work zones, intersections, roundabouts, and pedestrian crossings [2]. Katz [3] reported effective and statistically significant speed reductions of about 12% in vehicle speeds.

In 2010-2011, Zamora and Hildebrand [4] tested the performance of transverse pavement markings in Canada, as a speed reduction countermeasure for intersections in the City of Fredericton, NB, in coordination with the City. Until then, the influence of this countermeasure in the Canadian context had been almost undocumented [5]. The experience and results in Fredericton were the starting point for the design and evaluation of transverse pavement markings in Costa Rica during 2013-2014 [6]. Based on the results of the effectiveness of five different peripheral and transverse pavement marking patterns in Fredericton, full lane width transverse pavement markings were proposed for three locations in Costa Rica's central metropolitan area. Transverse markings are placed perpendicular to the direction of the traffic flow. Following Rutley's approach, progressively narrower spacing between lines were tested at two sites, and four groups of six equally-spaced lines were installed at the third site.

METHODOLOGY

The overall goal of the project is to study the effectiveness of transverse pavement markings on driver behaviour, as a low-cost speed reduction countermeasure. A general diagnosis of the road network was undertaken in order to identify possible sites for the study. The diagnosis took into account high-risk accident locations, high speed areas (above posted speed limits), and particular conditions, particularly pedestrian exposure, road alignment, and intersections.

Three sites were selected for the installation of transverse pavement markings, and two different patterns were designed, installed and tested. For both designs, full lane width transversal lines were proposed, but with a different spacing design. Peripheral markings were not included in the test, as well as any other alternative transverse marking patterns.

Regarding the materials, performed tape markings were used in Fredericton, whereas for the Costa Rican project double-layered white thermoplastic material was proposed for the installation of the 10-cm wide transverse lines. The two layers of thermoplastic material gave enough thickness for vehicles to feel the vibration as travelling through the reduction speed area. Passenger vehicles were more likely to feel this effect, similar to rumble strips.

In terms of spacing design, the first two sites followed a progressively narrower logarithmic spacing pattern, and for the third site, the pattern consisted of four equally-spaced groups of six equally-spaced bars, as shown in Figure 1. Equation 1 was used to obtain the spacing of the lines for the logarithmic pattern. In the equation, *x* is the number of line (from 1 to 25) and *y* is the spacing in meters. This equation corresponds to a theoretical speed reduction of 40 km/h.

$$y = -3{,}94 \cdot \ln(x) + 15{,}49 \qquad (R^2 = 0{,}996) \tag{1}$$

Two main conditions were considered to evaluate the effectiveness of the countermeasure: differences between the two installed patterns, and the over time effect, i.e. short-term versus long-term, up to 6 months after the installation. This study did not include the impact of the markings at night time, only during daylight and with normal weather conditions.

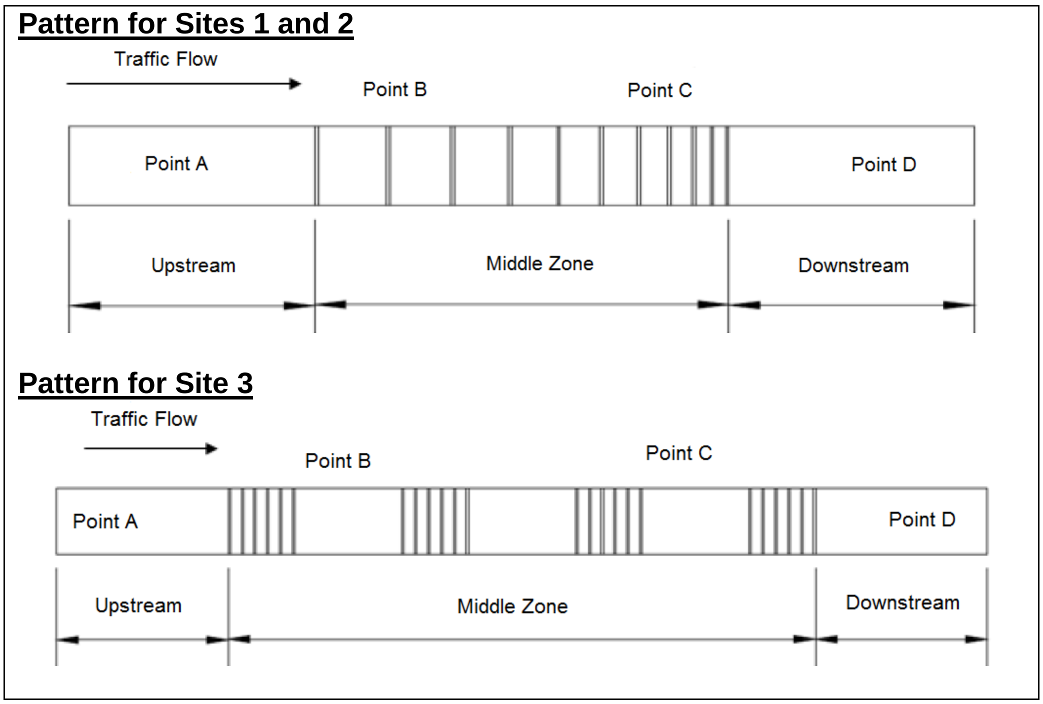


Figure 1 – Transverse pavement marking patterns tested in Costa Rica.

Description of the Sites and Installation of the Markings

Several sites were explored in the capital city, San José, and its surrounding areas, both in urban and rural highways and roads. Sample speed data were collected to verify non-compliance of the speed limits.

Site 1. This site had been previously identified by Road Safety Audits as a high-risk accident location for pedestrians. The facility is a 90 km/h four-lane divided highway connecting two main cities, and carrying over 40,000 vehicles per day, based on data from 2012. In a busy hour, more than 110 pedestrians were counted crossing the highway at this point (Figure 2), including schoolchildren and parents with babies on strollers. There are residential areas and schools close to both sides of the highway. At this point there are no pedestrian facilities, and there is an evident need to cross the highway. Transverse lines with a progressively narrower logarithmic spacing were installed in the westbound direction (Figure 3) in order to mainly increase alertness on drivers, and maybe encourage speed reduction, which would have an impact on the risk to pedestrians needing to cross at this point. Speeds tend to be higher in this highway section due to a smooth road alignment (Figure 4).

Figure 2 – Pedestrians crossing the highway at Site 1.

Figure 3 – Installation of markings at Site 1.

Site 2. Located on the same 4-lane divided highway as site 1 (Figure 4), with a distance of about 6 km from Site 1, but in the opposite direction (eastbound), this section carries over 45,000 vehicles per day (year 2012). In this highway, heavy vehicles represent 18 to 21% of the average daily traffic (ADT). The specific location is a downgrade slope right before a sharp horizontal curve (Figure 5), reason why the posted speed drops to 60 km/h in this section. This site was selected due mainly to its road alignment, which is not consistent with the operating speeds. Transverse lines with progressively narrower logarithmic spacing were installed (same as Site 1). A total of 25 transverse lines were placed in each site, with spacings varying from 16 m to 2.5 m at the end of the speed zone, as it can be appreciated in Figure 5. Agent [7] had tested transverse markings in Kentucky, USA, in a sharp horizontal curve, achieving a maximum speed reduction of 25 km/h; although a novelty effect was also observed.

Figure 4 – Location of testing sites 1 and 2 (aerial view)
Source: Google Maps, 2015

Site 3. The third site is located in a rural two-lane low-traffic mountainous road, specifically in a road section with moderate slopes and horizontal curves, with a posted speed of 40 km/h. This road has an average daily traffic of about 3,000 vehicles per day, with an 18% of heavy vehicles (yr. 2012). A different pattern was tested, which consisted of four groups of transverse lines installed with a separation of 30 m between groups. Each group consisted of six lines with a constant spacing of 0.5 m (Figure 6).

Figure 5 – Installation of markings at Sites 2.

Figure 6 – Installation of markings at Sites 3.

There is a nearby school, thus the posted speed lowers down to 25 km/h, a speed limit largely ignored by drivers. The crossing of schoolchildren motivated the selection of this site. The location of Site 3 is shown on Figure 7:

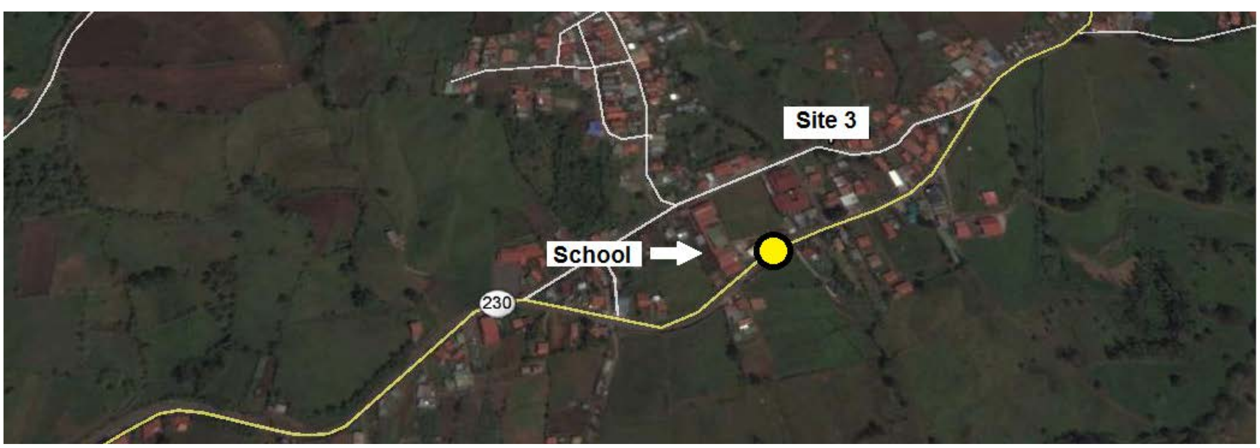


Figure 7 – Location of testing site 3 (aerial view)
Source: Google Maps, 2015

Data Collection

Data were collected following similar considerations as it was carried out in Fredericton by Zamora & Hildebrand [4]:

- Speed readings were taken from inside a vehicle, and positioned as inconspicuously as possible to avoid any interference with driver behaviour and speed choice. The vehicle was parked on the right shoulder, or at least as far from the travel lane as possible.
- Before each new set of speed readings, the hand held digital speed radar was recalibrated to ensure accurate readings, and single-direction speed detection was set in the radar, in order to avoid interference with speed readings of the oncoming traffic.
- Individual speed readings were collected using random sampling, and whenever vehicles were moving in a platoon, only the first vehicle speed was considered, because in most cases the speed of the following vehicles are being influenced by the first one, driving at the same speed or even less. Observations of free-flow speed are an important requirement for this kind of experiment.
- On a data collection day, a minimum sample of 30 readings were collected starting at Point A, then moving on to points B, C and D, for a minimum of 120 readings per site, per day. Due to limitations of the handheld speed control device, changes of speeds of the same vehicle throughout the speed zone were not measured, therefore data were collected one spot at the time.
- Data collection took place avoiding peak hours, in order to experience more free-flow speeds. Traffic queues and platoons influence operating speeds, reason why they must be avoided as possible.
- Adverse weather conditions (rainstorms and fog) were avoided to normalize as many external variables as possible.

Experimental Design

Following a similar approach as Zamora & Hildebrand [4], speed data were collected before and after the installation of the markings at the three sites, and the before speed data were taken as the control group. For this project, four speed data collection spots were defined at each site, as it was shown previously in Figure 1: Point A (upstream), Point B (middle zone at the beginning of the speed zone), Point C (middle zone at the end of the speed zone), and Point D (downstream). A speed profile was developed for each set of readings.

Thirty speed readings were collected at each spot, each day. The first set of readings were taken shortly before the installation of the markings, and then several days up to 6 months after the installation. Markings were installed on February 21, April 12 and August 30 (of 2013), respectively at sites 1, 2 and 3; therefore more data were collected on Site 1, for a total of 2,050 speed readings. At Site 2, 1100 readings were collected, and 600 readings at Site 3.

The statistical analyses were performed using the Student's T-test, which is very commonly used to compare means between two groups of data. Significant speed reductions were identified with a 95% level of confidence, and both average speed and 85th percentile speed were compared and analysed. For the purpose of this paper, more emphasis was given to the 85th percentile speed, as it better represents the operating speed.

RESULTS AND ANALYSIS

For a "before and after" study approach, the Highway Capacity Manual [8] states that *"it is appropriate to utilize such studies when it is reasonable to assume the "before" conditions would be repeated in the "after" period if the improvement had not been implemented"*. For this experiment, as well as for the one performed in Fredericton, this means that the speed profile in a particular site would have remained statistically the same if the markings had not been installed.

For the statistical analysis, the Anderson-Darling test of the Minitab software was used in order to assure that the collected data followed a normal distribution, resulting in several outliers that were to be deleted from the sample. This step is very important while working with statistical approaches such as the Student's t distribution or the F distribution. A 95% level of confidence was used throughout the analysis, which is mostly used in the transportation field. If the null hypothesis were to be rejected, this will mean that it is 95% (or more) certain that there is a significant difference in the speed of vehicles due to the installation of the markings. A two-tail Student's t distribution was used.

Site 1: A sample of 360 readings were collected before the installation of the markings at all the spots: upstream, middle zone and downstream. The "after" data were collected the day after the markings were installed, 4 days after, and then approximately on the following timings: 1 week, 2 weeks, 1.5 months, 7 weeks, 2 months, 2.5 months, 3 months, 4 months, 5 months, 6 months, and almost 7 months after the installation, for a total of 1690 speed readings. An overall summary is presented on Figure 8, including the overall average and 85th percentile speeds for each measuring spot, and the speed reductions achieved in percentage.

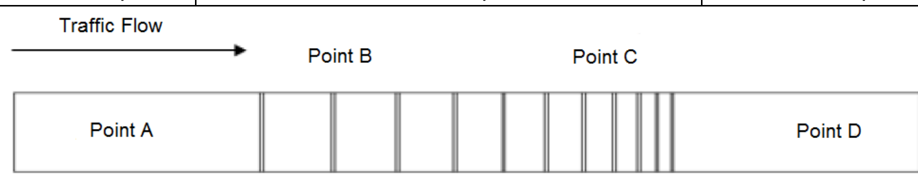
SITE 1	Upstream	Middle Zone		Downstream
V_{85th} (BEFORE)	99.0 km/h	94.2 km/h		96.3 km/h
V_{avg} (BEFORE)	84.0 km/h	80.8 km/h		83.7 km/h
Posted Speed 				
V_{85th} (AFTER)	95.5 km/h	92.3 km/h	89.7 km/h	89.4 km/h
V_{avg} (AFTER)	86.4 km/h	83.5 km/h	80.9 km/h	80.6 km/h
Max. reduction V_{85th} (Before vs. After)	**7.4%**	**6.6%**	**9.7%**	**15.9%**
Max. reduction V_{avg} (Before vs. After)	0.7%	-0.8%	**3.7%**	**9.1%**
Avg. reduction V_{85th} (Point D vs. Point A)	|-->			**6.4%**
Avg. reduction V_{avg} (Point D vs. Point A)	|-->			**6.8%**

Figure 8 – Speed data summary for Site 1. [6]

Regarding the "before" data, the 85th percentile speeds are not overwhelmingly above the posted speed and the average speeds are even lower than the posted speed, nevertheless the problem in this site is the crossing of pedestrians in a very straight road segment that encourages higher speeds and inattentiveness. The main goal of the markings is to alert drivers in this particular road section, even if speed reductions might not be considered significant. The most significant speed reductions were observed on points C and D, at the end of the speed zone and downstream, as expected. The 85th percentile speed lowered down to 89 km/h, and the average speed to 80 km/h. According to the statistical analysis, only some of the measurements at Point D were statistically significant (below 80 km/h).

Figure 8 also shows the speed reductions (in percentage) comparing the data after the installation of the markings with the "before" data. It can be seen that the maximum reductions took place downstream (Point D), almost achieving a 16% speed reduction on the operating speeds (85th percentile). The average reduction of speeds between points A and D (i.e. throughout the speed zone) was calculated to 6.8% on average speeds, and to 6.4% on 85th percentile speeds. In this road section there is a very subtle -but still present- negative grade, therefore the results show that drivers had to use their brakes throughout the speed zone, which gives as well a sense of alertness.

Site 2: Readings were collected 2 days after the installation of the markings, and then 2 weeks, 3 weeks, 1.5 months, 2.5 months, 4 months, 4.5 months, and 5.5 months after, for a total of 1100 readings. This site reported the largest sample of statistical significant speed reductions (Figure 9), not only downstream (at Point D) but also in the middle zone (at Points B and C). All speed data readings at points C and D were statistically significant throughout the analysis period, in terms of speed reductions compared to the "before" data.

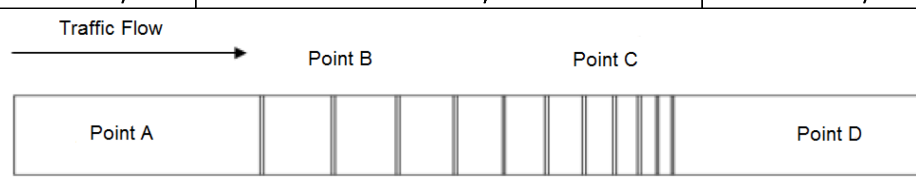
SITE 2	Upstream	Middle Zone		Downstream
V_{85th} (BEFORE)	78.3 km/h	82.0 km/h		81.7 km/h
V_{avg} (BEFORE)	71.3 km/h	75.3 km/h		71.6 km/h
Posted Speed 				
V_{85th} (AFTER)	83.6 km/h	78.3 km/h	73.3 km/h	68.3 km/h
V_{avg} (AFTER)	73.6 km/h	68.9 km/h	64.0 km/h	61.2 km/h
Max. reduction V_{85th} (Before vs. After)	3.4%	**15.9%**	**15.1%**	**19.2%**
Max. reduction V_{avg} (Before vs. After)	2.5%	**20.5%**	**18.5%**	**17.2%**
Avg. reduction V_{85th} (Point D vs. Point A)	|-->			**18.3%**
Avg. reduction V_{avg} (Point D vs. Point A)	|-->			**16.7%**

Figure 9 – Speed data summary for Site 2. [6]

Average speeds decreased to 61 km/h (maximum average speed reduction of 17%), and the operating speed to 68 km/h (maximum operating speed reduction of 19%). Figure 9 summarizes speed data and speed reduction percentages for Site 2. The average speed reduction between points D and A was calculated to 16.7% on the average speed, and to 18.3% on the operating speed, both among the most significant speed reductions obtained throughout this project.

Figure 10 shows the operating speed profile at this site, including the "before" speed data, the "after" speed data on average throughout time, and the posted speed limit.

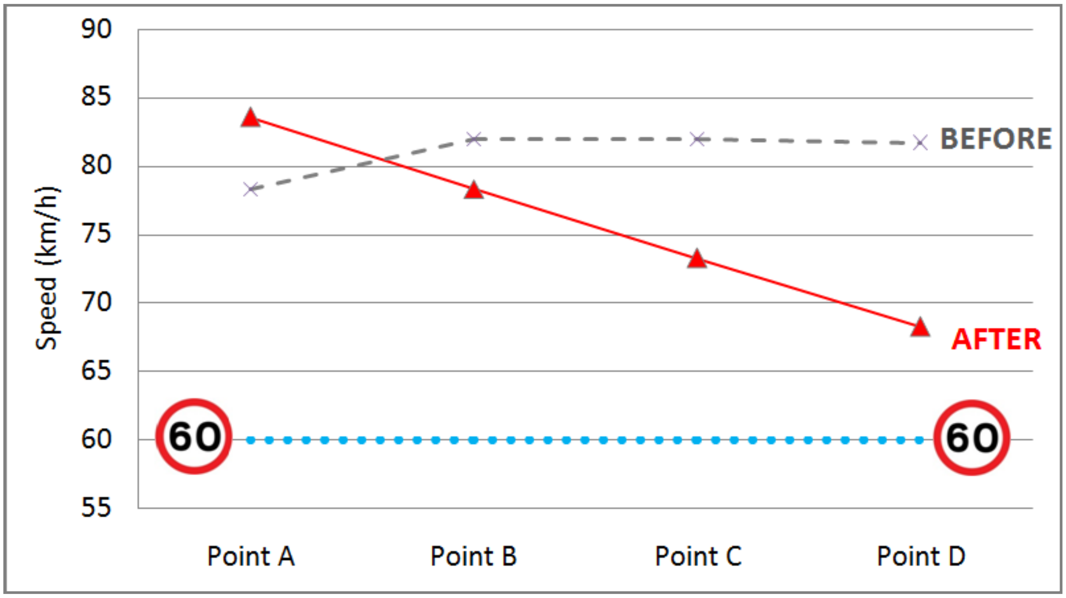


Figure 10 – Operating Speed Profile for Site 2.

Site 3: Figure 11 summarizes the speed data for the third site, including maximum speed reductions comparing the before and after data, and average speed reductions between points A and D. The pattern installed in this area differs from the one installed in the other two sites, and the road conditions are different as well, reason why comparisons among sites were not part of the analysis. Speeds observed in this rural road are overall lower than for sites 1 and 2, but still high compared to the 40 km/h speed limit, and even more critical considering the school zone with a 25 km/h speed restriction.

At Point C, all speed data collected showed significant speed reductions: 1 week after the installation of the markings, 3 weeks, 1 month and 7 weeks after, for a total of 600 readings. The maximum average speed reductions were observed at the end of the speed zone: 9.3% and 9.7%, respectively at points C and D. In terms of the average speed reductions between points A and D (the effect of slowing down throughout the speed zone), an 8.3% on average speed reduction was achieved, and an 8.6% on operating speed reduction.

SITE 3	Upstream	Middle Zone		Downstream
V_{85th} (BEFORE)	69.0 km/h	65.3 km/h		61.3 km/h
V_{avg} (BEFORE)	61.0 km/h	57.4 km/h		54.8 km/h
Posted Speed 				
V_{85th} (AFTER)	67.1 km/h	64.5 km/h	63.9 km/h	61.3 km/h
V_{avg} (AFTER)	58.5 km/h	55.5 km/h	52.8 km/h	53.6 km/h
Max. reduction V_{85th} (Before vs. After)	5.8%	4.1%	5.6%	2.6%
Max. reduction V_{avg} (Before vs. After)	6.4%	5.1%	**9.3%**	**9.7%**
Avg. reduction V_{85th} (Point D vs. Point A)	|--->			**8.6%**
Avg. reduction V_{avg} (Point D vs. Point A)	|--->			**8.3%**

Figure 11 – Speed data summary for Site 3. [6]

CONCLUSIONS AND RECOMMENDATIONS

In general terms, road safety infrastructure countermeasures in Costa Rica have not been documented nor studied. It has been, on the contrary, mainly empirical. The development of a Road Safety Manual adapted to the actual conditions of the country and its road safety culture has raised the need to evaluate the effectiveness of these countermeasures.

In terms of transverse pavement markings for speed control, different patterns and materials have been tested worldwide. Even though more testing is encouraged in order to keep evaluating the effect of these markings in different road environments and with different pattern designs, results have shown an almost generalized positive impact in terms of speed reduction, therefore their use on the national road network is encouraged. Sites must be carefully selected taking into account traffic accidents, design and operating speeds, vulnerable users, road alignment, and particular infrastructure characteristics.

After analyzing the data collected at the three sites, the following conclusions have been drawn:

- In all the three sites, statistically significant speed reductions were observed. For the progressively narrower spacing pattern on the first two sites, there was clear evidence that drivers have a higher tendency to reduce their speeds towards the end of the speed zone (marked area). This behaviour was not that evident at the third site, probably due to the fact that the transverse lines were not continuous, but installed in equally-spaced groups of lines.

- A novelty effect was not observed in all three sites, which is desirable in terms of implementing this countermeasure in other locations on the national road network. Site 1 was monitored up to almost 7 months after the installation of the markings, and still statistically significant speed reductions were observed.
- At the first site, statistically significant reductions were mainly observed on the downstream area, achieving maximum speed reductions of almost 16% on the operating speed. This is a complicated highway section due to a quite flat and relatively straight road alignment with good visibility. There is a slight downgrade slope and a posted speed of 90 km/h, therefore drivers tend to speed up. There are no evident reasons why to reduce the speed in this site, so the main purpose of the transverse lines was to alert drivers, even though there was not a clear sign of pedestrian crossing at this location. Average speed reductions between points A and D (upstream and downstream) were above 6%, which is considered satisfactory because of the aforementioned highway particularities.
- The second site was the one reporting the largest speed reductions overall. Drivers will start lowering down their speeds in the middle zone and then on the downstream zone. This behaviour was expected as there is a downgrade slope with a posted speed of 60 km/h, although most drivers go much faster (average operating speed of 82 km/h). Maximum speed reductions of up to 20% were observed on the operating speeds, and about 17% on the average speeds.
- Finally, the third site, consisting of a very different road environment and a different transverse line pattern design. At this site, a maximum of 5% in speed reduction was observed in the middle zone on the operating speeds, and of 9% on the average speeds. As it was previously explained, there is a 40 km/h speed limit on this rural road, although at school zones, the limit drops down to 25 km/h. Most drivers do not respect this limit, therefore the purpose of the markings was mainly to alert drivers of the school zone. Average speed reductions between points A and D (upstream and downstream) were above 8%.

This experiment led to the same overall conclusion as in the evaluation of transverse and peripheral pavement markings in Fredericton [5]:

> *"Driver behaviour is very difficult to measure when it comes to road safety countermeasures and confounding variables are difficult to control. In the context of this study, speed is the only measurable metric that can give us an idea of the effect of these markings. Speed reduction is consequently used as a proxy to estimate an improvement in safety. One very important aspect that cannot be measured is the driver's awareness or attentiveness. Since the markings look quite unique, they also serve to alert the drivers to an unusual condition."*

Further research on the effectiveness of low-cost road safety countermeasures such as transverse pavement markings is encouraged, as well as considering a longer-term study period. On future installation of transverse markings, a thicker layer of thermoplastic material is highly recommended in order to increase the noticeability of the lines. The vibration effect, similar to the effect of rumble strips, is important in the Costa Rican context due to the driving culture in the country, more exposure of vulnerable users, and insufficient enforcement. Drivers tend to drive faster than the posted limits therefore increasing the risk of traffic accidents.

Adverse conditions were not considered for this project, as previous speed studies have shown a tendency of drivers to slow down and drive more carefully during rainstorms and foggy conditions, which can be critical in the country. Future related projects will consider night condition as well, in order to compare the effect day versus night.

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