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Can zigzag marking improve pedestrian safety at unsignalized crosswalks? An observational before-after study in Israel

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Abstract

Zigzag road marking near unsignalized pedestrian crosswalks is common in some countries but not yet allowed in Israel. An observational before-after study was conducted to explore its impacts on pedestrian crossing conditions. The measure was applied at three midblock urban crosswalks, on dual-carriageway and two-lane roads. The study examined changes in safety-related behaviors by comparing three periods: before the installation, and two weeks and two months afterwards. Shortly after the zigzag application, a significant decrease in average vehicle speeds, of 9%-16%, was observed at all study sites, but in a longer-term a decrease of 7%-8% remained at the dual-carriageway sites only. A relative increase in yielding rates to pedestrians was of 19%-20% in the short-term and of 13%-14% after two months, at dual-carriageway sites, with no change at the two-lane site. Overall, zigzag marking may improve pedestrian safety. However, as the effects were inconsistent, it was not recommended for widespread use.

Keywords: Pedestrian crosswalk; zigzag marking; behavior observations; speeds; yielding to pedestrians.

1. Introduction

Pedestrians are the most vulnerable group of road users, representing a quarter of road fatalities worldwide (World Health Organisation, 2018; Shinar, 2017). In Israel, over the past decade, pedestrians have accounted for a third of total fatalities and over a fifth of serious road injuries (Road Safety Authority, 2021). Most pedestrian casualties occur in urban areas, indicating the need to devise and promote conditions for safe pedestrian mobility within sustainable urban development programs (Planning Administration, 2020). The concept of walkability is also important in this context (Campisi et al., 2021; Stabile et al., 2023), to ensure safer and inclusive urban spaces for all pedestrians. In particular, safe crossing conditions should be provided at unsignalized crosswalks, where a quarter of severe pedestrian accidents occur (Road Safety Authority, 2021).

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Unsignalized crosswalks are considered as particular hazardous locations due to frequent conflicts between pedestrians and vehicles (Koepsell et al., 2002; Crowley-Koch et al., 2011). The main reasons for pedestrian injury at such crosswalks include drivers' fail to give-way to pedestrians and high vehicle speeds, which are also associated with the severity of pedestrian injury (Leaf and Preusser, 1999; Mead et al., 2014; Shinar, 2017). Thus, it is important to identify and implement measures that may contribute to reducing driving speeds when approaching midblock crosswalks, since drivers do not always expect pedestrians to be on the road, while road conditions often allow vehicles to exceed the speed limit.

International literature suggests various infrastructure measures with a potential for improving pedestrian safety, by means of reducing travel speeds, enhancing visibility of crosswalks and/or alerting drivers to the presence of pedestrians (Gitelman et al., 2012; Mead et al., 2014; Mitra et al., 2021). At unsignalized crosswalks, such measures may include, e.g., setting speed humps or road narrowing (Gitelman et al., 2012; Mead et al., 2014; Gitelman et al., 2017), adding special vertical signs with a message on giving-right-of-way to pedestrians (Van Houten and Malenfant, 1992; Huybers et al., 2004; Benekohal et al., 2007) or signs on the roadway with speed limits or an alert, such as “slow” (Fuller and Santos, 2002; Mitra et al., 2021). Another measure is the placement of zigzag road markings adjacent to unsignalized crosswalks. This measure is implemented in countries such as the United Kingdom, Australia, New Zealand, South Africa (Mutabazi, 2010; Dougald et al., 2012), and was also examined by research studies in some countries.

Zigzag markings have several uses, e.g., warning drivers about a crosswalk, prohibiting parking and/or overtaking, or preventing pedestrians from crossing outside the crosswalk area (Dougald et al., 2012), which vary among countries. In the UK, drivers are prohibited from parking in a zigzag area, and also from overtaking to prevent overtaking other vehicles that have stopped to give-way to pedestrians in the adjacent lane (Mutabazi, 2010). In Australia, zigzag markings were permitted as a supplementary measure at marked crosswalks where visibility is limited due to horizontal or vertical bends (Department of Main Roads, 1988). In South Africa, zigzag markings restrict vehicles from changing lanes near crosswalks (Ribbens, 1996).

Several studies examined the impacts of zigzag markings on road user behaviors. In the UK, zigzag markings of about 20 m on each side of the crosswalk were introduced in 30 roads, with the aims of preventing vehicles from overtaking before the crosswalk and of warning pedestrians not to cross in the zigzag area (Wilson, 1974). Using before-after comparisons, the study Wilson (1974) found a 14% decrease in the rate of pedestrians crossing in the zigzag area and a 20% reduction in vehicles' overtaking. In the USA, Dougald et al. (2012) examined the effect of zigzag marking on travel speeds. The measure was introduced on two roads, a two-lane road with 70 km/h speed limit and a divided road with 65 km/h speed limit and two lanes per direction, with various crosswalk visibility distances. The study found that one week after the zigzag placement, there was a significant decrease in average speeds of 5 km/h at a distance of 150 m from the crosswalks, and of 1.5–10 km/h near the crosswalks, and the effect was maintained for the longer term, after six months and a year. Furthermore, when a pedestrian was on the crosswalk, a significant decrease in speed was observed at all distance ranges from the crosswalk.

In general, previous literature pointed to inherent safety potential of zigzag marking. In addition, it is a low-cost and easily implemented infrastructure measure that may have a wide use. Since zigzag marking is not yet permitted under Israel’s National Traffic Sign

Code (Ministry of Transport, 2020), the National Road Safety Authority initiated a study to explore the impact of zigzag marking on pedestrian crossing conditions. In the study, zigzag markings were introduced in the vicinity of midblock crosswalks on two urban roads and an observational before-after study was conducted to examine the associated changes in road user behaviors. The study aimed to examine the safety effects of introducing zigzag road markings as a means of warning drivers about an upcoming midblock crosswalk on an urban road. It was expected that zigzag marking would attract drivers' attention and prompt them to slow down and increase their vigilance when approaching the crosswalk.

2. Materials and methods

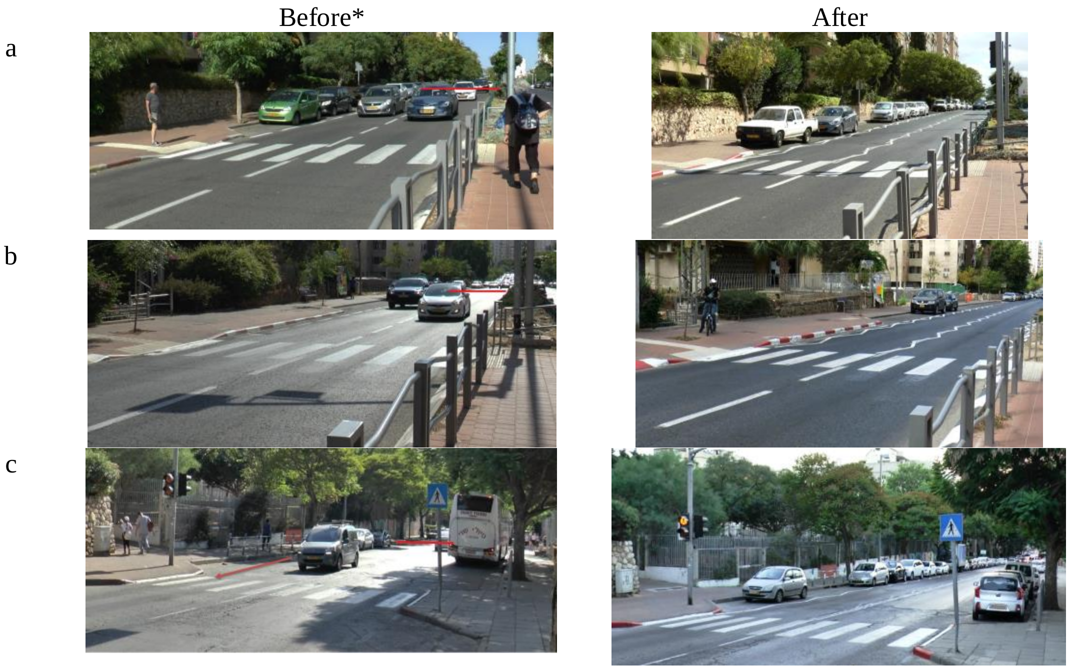
2.1 Study sites

In the study, zigzag markings were added before three marked midblock crosswalks in the city of Holon, in central Israel. The measure was applied on two types of roads:

(1) A dual-carriageway road with a built median and two lanes in each travel direction, where the zigzag marking was introduced in both directions; we defined treated *Site 1* for direction east-west and treated *Site 2* for direction west-east;

(2) A two-way street with one lane in each direction, where the zigzag marking was introduced in one direction (treated *Site 3*).

All treated sites were with 50 km/h speed limits. Figure 1 shows the treated sites before and after the application of zigzag markings. Zigzag lines were painted on the fifty meters of road approaching each crosswalk.



*A horizontal red line indicates 50 m distance from the crosswalk.

Figure 1: Study sites before and after the application of zigzag markings: (a) Site 1, on Alufei Tsahal str., direction east-west; (b) Site 2, on Alufei Tsahal str., direction west-east; (c) Site 3, on Keren HaYesod str. (All sites are in the city of Holon.)

In addition, two comparison-sites were selected for treated Sites 1-2, situated on another dual-carriageway road in the same city (Mifratz Shlomo str.) and with similar travel directions, where no treatment was applied and speed measurements were performed during the study periods. (For treated Site 3 a comparison-site was not found in the city.)

2.2 Data Collection and Analyses

To examine the impacts of zigzag marking, the study focused on safety-related behaviors of road users, such as vehicle speeds when approaching the crosswalk, yielding to pedestrians by drivers at crosswalks, and pedestrian crossing behaviors, e.g. stopping and checking the road traffic before crossing, and crossing within the designated crosswalk. These behavior types have a proven relationship to pedestrian safety at crosswalks (Ewing and Dumbaugh, 2009; Mead et al., 2014; Gitelman et al., 2017). The study included measuring changes in the behaviors after the zigzag marking introduction as compared to the before period, which were examined in the short term - two weeks after the measure's application, and in the longer term – after two months. The data were collected in June, September and November 2016, which were defined, respectively, as *before*, *after1* and *after2* periods.

Speed measurements were conducted using a Bushnell speed radar gun, and took place on weekday mornings (between 9-13) and evenings (between 16-20). To note, this speed gun measures the speed of a car from 16-322 km/h with two km/h accuracy, and it is commonly applied in the national speed surveys on urban roads in Israel (Gitelman, 2014). To obtain free-flow speeds, the first vehicle in a group was measured, with no other vehicles in front of it, in the distance of 30 m, at least. Each vehicle was measured twice, at the entrance to the crosswalk approach zone and adjacent to the crosswalk. Speed measurements were performed at all treated sites and two comparison-sites. For each site, driving speeds in the crosswalk approach zone were measured in two situations: with a pedestrian on the crosswalk (50 vehicles), and without a pedestrian on the crosswalk (100 vehicles). The sample size needed for each case was defined enabling to identify differences of 5 km/h as significant with a 95% confidence interval and a statistical power of 80% (Cohen, 1988).

To collect data on other behaviors (vehicles' giving-way to pedestrians, pedestrian crossing behaviors) unobtrusive video-cameras observations were used. Video-observations were performed only at the treated sites. In each round of observations, 10 hours were recorded to capture peak and off-peak hours of both vehicle traffic and pedestrian activity. In addition, based on the video-records, background site characteristics were produced as to the hourly traffic volumes and the number of crossing pedestrians, and pedestrian characteristics (gender, age).

To examine the significance of changes in travel speeds and background site characteristics, ANOVA tests and *post hoc* tests (Tukey HSD) were applied (Randolph and Myers, 2013). Furthermore, a Kruskal-Wallis and Kolmogorov-Smirnov (K-S) tests were used to examine differences between the speed distributions in various periods. To examine the differences in other behavior indices, we applied a Pearson's chi-square test.

3. Results

3.1 Background site characteristics

Prior to examining changes in road user behaviors, we considered changes in the background characteristics of the study sites between the periods (Table 1). Overall, no significant changes were observed between the study periods in terms of the average hourly vehicle volumes and the numbers of crossing pedestrians; at all study sites, no significant association was found between the study periods and the time of measurement (morning/evening). During the study, hourly vehicle traffic volumes were: at Site 1 – in the range of 600-700 in the morning and 900-1,100 in the evening; at Site 2 – 400-600 and 400-500, respectively; at Site 3 – 200-300 and around 300. The mean values of the hourly numbers of crossing pedestrians were 70-110 at Sites 1-2 and lower, 20-50 at Site 3. Furthermore, no significant differences between the rounds were found in pedestrian gender ($p=0.151$, $\chi^2(2)= 3.77$). As to pedestrian age groups, in the *after1* period, slightly more adult pedestrians (ages 19-64) were observed compared to the other periods (67% vs. 61%, $\chi^2(6)=27.85$, $p<0.001$); such differences may be related to natural fluctuations in pedestrian volumes and their characteristics at different months.

Table 1: Hourly vehicle and pedestrian traffic at the study sites, in various study periods.

a – Mean hourly vehicle traffic (s.d.)

Period	*Site 1*		*Site 2*		*Site 3*	
	Morning	Evening	Morning	Evening	Morning	Evening
Before	668 (55)	1,077 (174)	590 (78)	473 (61)	255 (23)	295 (65)
After1	623 (37)	1,061 (156)	534 (97)	476 (59)	228 (35)	308 (29)
After2	623 (36)	1,019 (192)	524 (160)	468 (52)	191 (24)	292 (46)

b – Mean hourly number of crossing pedestrians (s.d.)

Period	*Site 1*		*Site 2*		*Site 3*	
	Morning	Evening	Morning	Evening	Morning	Evening
Before	70 (49)	107 (16)	92 (67)	82 (20)	26 (17)	28 (22)
After1	88 (63)	102 (15)	88 (63)	113 (12)	25 (24)	33 (20)
After2	78 (51)	90 (33)	81 (71)	100 (50)	20 (20)	50 (42)

3.2 Vehicle speeds

Table 2 shows vehicle speed indicators in the area approaching the crosswalk and near the crosswalk, at each treated site, when a pedestrian was present on the crosswalk. The analyses showed that as to the average driving speeds in the approaching area:

- At Site 1, a significant difference was found between the three periods ($F(2,147)=3.68$, $p<0.05$). After introducing the zigzag marking, a significant decrease of 4 km/h was observed compared to the *before* period, and the effect was maintained in the longer term ($p<0.05$).
- Similarly, at Site 2, the difference between the three periods was significant ($F(2,147)=8.73$, $p<0.001$). In the *after1* period, a decrease was of 7 km/h ($p<0.001$), but in the *after2* period related to *before*, the difference was insignificant.
- When considering both sites together, the difference between the three rounds was significant as well ($F(2,297)=10.90$, $p<0.001$). In the short term, there was a significant decrease of about 6 km/h, from 47.5 to 41.7 km/h, and this effect was maintained after two months, albeit to a lesser extent, 3.5 km/h ($p<0.05$).
- At Site 3, a significant difference was found between the three rounds ($F(2,147)=6.31$, $p<0.01$). In the *after1* period compared to before, a significant decrease of 4.5 km/h was observed, but disappeared two months later.

At all treated sites, a decrease in the 85th percentile speed in the area approaching the crosswalk was observed, as well. However, no significant differences were found between the periods in vehicle speeds near the crosswalks (see Table 2).

Table 2: Vehicle speeds in the crosswalk approaching area of the treated sites, when a pedestrian was present.

Site*	Period	*Average speed, km/h* upon entrance	near crosswalk	*s.d., km/h* upon entrance	near crosswalk	*85th percentile speed, km/h* upon entrance	near crosswalk
Site 1	Before	48.0	34.1	9.9	18.1	58.3	50.3
	After1	43.8&	32.8	8.6	18.7	53.3	49.7
	After2	44.0&	31.6	7.6	19.2	53.3	48.7
Site 2	Before	47.0	16.5	9.6	22.6	55.3	47.3
	After1	39.6&	21.5	9.0	20.6	51.0	48.0
	After2	43.9	21.6	8.0	19.0	50.3	45.3
Sites 1+2	Before	47.5	25.3	9.7	22.2	56.8	48.0
	After1	41.7&	27.1	9.0	20.4	52.0	48.8
	After2	44.0&	26.6	7.8	19.7	51.8	46.0
Site 3	Before	41.8	24.7	8.0	14.2	52.3	39.0
	After1	37.4&	18.8	7.8	17.9	46.0	37.3
	After2	42.2	23.8	6.2	17.3	49.0	41.0

* N=50 at each site. &p<0.05 in comparison with before period, *post hoc* tests.

In addition, differences in the distributions of travel speeds between the three rounds were examined and showed that, at all sites, significant differences were found in the distribution of travel speeds upon entering the area approaching the crosswalk. For example, at Site 1, the difference was significant ($\chi2(2)=7.85$, $p<0.05$) and attributable to the difference between the speed distributions in the *after2* period related to *before* (K-S test: $p<0.01$). At Site 3, the difference between the three distributions was significant ($\chi2(2)=14.37$, $p<0.01$), but attributed to the difference between the speed distributions in the *after1* vs. *before* period (K-S test: $p<0.01$). In general, across the study sites, the differences in speed distributions between the rounds, in the crosswalk approaching areas, were mainly related to lower speeds in the *after1* period. At the same time, at all study sites, no significant differences between the periods were found in the distribution of vehicle speeds near the crosswalks.

Table 3 shows the speed indicators estimated in the area approaching the crosswalk and near the crosswalk, at each treated site, in situations when there were no pedestrians on the crosswalk. At all three sites, no significant differences were found between the study periods in mean driving speeds, both in the approaching area and near the crosswalks. Similarly, no significant differences were found between the rounds in the analysis of speed distributions.

Speed measurements were also conducted at two comparison-sites (of Sites 1-2), during similar periods. The findings showed (Table 4) that when a pedestrian was on the crosswalk, at comparison-site 1, a significant difference was found between the periods in mean travel speeds at the entrance to the crosswalk approaching zone ($F(2,147)=12.42$, $p<0.001$), which was related to a significant decrease in the mean speed (of 6.5 km/h) in the *after2* period compared to *before*. At comparison-site 2, no difference in travel speeds was observed between the periods. Similar to the treatment-sites, at the comparison-sites, no significant differences between the periods were found in speeds adjacent to crosswalks and when there were no pedestrians on the crosswalk.

Furthermore, average travel speeds upon entering the crosswalk approaching area (when a pedestrian was present on the crosswalk) were compared between the treated sites (Sites 1-2) and the comparison-sites. The findings showed that the difference between the two groups of sites was significant ($F(2,594)=6.40$, $p<0.01$), whereas the effect was mostly attributable to the difference between the treated sites (mean=41.7, s.d.=9.0) and the comparison-sites (mean=46.6, s.d.=5.9, $t(198)=-4.54$, $p<0.001$) two weeks after the zigzag markings were introduced. Figure 2 provides a visual comparison between the average speeds in two groups of sites. Regarding the vehicle speeds adjacent to crosswalks (when a pedestrian was present), and speeds in situations when no pedestrians were on the crosswalks, no significant difference was found between the two groups of sites.

Table 3: Vehicle speeds in the crosswalk approaching area of the treated sites, when a pedestrian was not present.

Site*	Period	*Average speed, km/h* upon entrance	near crosswalk	*s.d., km/h* upon entrance	near crosswalk	*85th percentile speed, km/h* upon entrance	near crosswalk
Site 1	Before	51.0	48.7	9.4	9.8	62.0	59.0
	After1	51.6	49.3	10.4	9.7	60.0	58.0
	After2	49.0	46.6	8.0	9.5	57.0	57.0
Site 2	Before	56.3	55.8	9.1	9.7	67.0	68.0
	After1	53.7	52.7	8.7	9.1	62.0	62.0
	After2	57.6	56.0	10.4	10.8	67.0	67.0
Sites 1+2	Before	53.7	52.3	9.6	10.4	64.0	62.8
	After1	52.7	51.0	9.6	9.6	60.8	60.8
	After2	53.3	51.3	10.2	11.2	64.0	62.8
Site 3	Before	43.2	37.2	6.4	7.1	50.0	44.0
	After1	41.3	37.3	7.6	7.7	48.0	46.0
	After2	42.8	37.0	7.7	7.7	49.8	45.8

* N=100 at each site.

Table 4: Vehicle speeds in the crosswalk approaching area of the comparison-sites, when a pedestrian was present.

Site*	Period	*Average speed, km/h* upon entrance	near crosswalk	*s.d., km/h* upon entrance	near crosswalk	*85th percentile speed, km/h* upon entrance	near crosswalk
Comparison-site 1	Before	49.3	27.6	9.3	22.7	60.3	51.3
	After1	48.2	25.1	5.7	22.0	53.7	50.3
	After2	42.8&	22.7	5.1	17.8	48.3	42.3
Comparison-site 2	Before	45.6	27.4	7.3	19.1	53.0	47.3
	After1	45.0	24.1	5.8	19.6	51.3	47.0
	After2	45.2	24.0	5.9	19.1	52.0	44.3
Comparison-sites 1+2	Before	47.5	27.5	8.5	20.9	56.8	48.8
	After1	46.6	24.6	5.9	20.7	52.0	48.0
	After2	44.0	23.4	5.6	18.4	50.8	42.9

* N=50 at each site. &p<0.05 in comparison with before period, *post hoc* tests.

3.3 Other behaviors

Other behaviors were collected at the treated sites only. The observations showed that when a pedestrian crossed on the dual-carriageway road sites, in 60% of cases there was a vehicle approaching the crosswalk in the near and/or far lane (related to the crossing pedestrian), whereas on the two-lane street, a vehicle was present in 55% of cases. The rate of vehicles giving way to pedestrians was estimated as the share of vehicles that slowed down or stopped to allow a pedestrian to safely cross, out of the total number of cases where there were vehicles present in the lanes approaching the crosswalk when a pedestrian was crossing. (Among the vehicles observed in the study, 90% were private cars, 6% - motorcycles, and 4% - buses or trucks.)

Figure 2: Average speeds in the crosswalk approaching area, at the treated sites (Sites 1-2) and their comparison-sites, when a pedestrian was present (in each case, average speed is given for two sites together).

The findings showed (Table 5) that in the rate of vehicles giving way to pedestrians:

- At Site 1 and Site 3, no significant differences were found between the study periods.
- At Site 2, significant differences were found in the near lane ($\chi2(2)=20.69$, $p<0.001$) and in the far lane ($\chi2(2)=12.61$, $p<0.01$), where the rates increased by 19% and 15% and by 16% and 10%, respectively, in two periods, after the zigzag markings were introduced.

Considering both treated sites on the dual-carriageway street together, significant differences were found in the rate of vehicles giving way to pedestrians between the rounds in the near lane ($\chi2(2)=14.42$, $p<0.01$) and in the far lane ($\chi2(2)=13.24$, $p<0.01$). The relative increase in this rate was of 14%-19% in the near lane and of 13%-20% in the far lane, while the change was higher in the *after1* period, see Table 5.

Table 5: Rates of vehicles giving-way to pedestrians at crosswalks, on the treated sites.

		On the near lane		*On the far lane*	
Site	Period	N*	Rate of giving-way	N	Rate of giving-way
Site 1	Before	290	61%	273	55%
	After1	302	66%	283	62%
	After2	255	62%	253	59%
Site 2	Before	242	53%	242	53%
	After1	217	72%&	212	69%&
	After2	212	68%&	222	63%&
Sites 1+2	Before	532	57%	515	54%
	After1	519	68%&	495	65%&
	After2	467	65%&	475	61%&

Site 3	Before	85	66%	--	--
	After1	122	71%	--	--
	After2	109	62%	--	--

* Number of cases observed. [&]p<0.05 in comparison with before period, chi-square tests.

Table 6 summarizes findings related to pedestrian behaviors, i.e. the percentage of pedestrians who stopped before crossing, who checked the traffic situation before crossing (e.g., turned their head to look in the direction of traffic), and who crossed within the crosswalk area. The findings showed that at all treated sites, changes in these pedestrian behaviors were minor, without consistent trends. For example, at Site 1, there was an increase in the share of pedestrians who checked the traffic before crossing, in the *after1* period vs. *before* ($\chi2(1)=9.18$, $p<0.01$) but no change in the *after2* period, and no differences between the periods in other behaviors. At Site 2, we observed a slight decrease in the share of those who crossed in the crosswalk area, in both after periods (with $\chi2(1)=10.64$, $p<0.01$, and $\chi2(1)=5$, $p<0.05$, respectively) but no significant changes in other behaviors. At Site 3, there was a slight increase in the rate of pedestrians who checked the traffic before crossing and crossed within the dedicated area, but only in the *after1* period and not in the longer term, see Table 6.

Table 6: Pedestrian crossing behaviors at the treated sites.

Site	Period	N*	*Percentage of pedestrians who* stopped before crossing	checked the traffic before crossing	crossed within the crosswalk area
Site 1	Before	506	38%	88%	63%
	After1	545	38%	93%[&]	64%
	After2	530	41%	90%	63%
Site 2	Before	495	33%	88%	77%
	After1	518	33%	90%	68%[&]
	After2	495	34%	88%	71%[&]
Sites 1+2	Before	1,001	35%	88%	70%
	After1	1,063	35%	92%	66%
	After2	1,025	38%	89%	66%
Site 3	Before	163	42%	94%	85%
	After1	202	45%	98%[&]	93%[&]
	After2	200	42%	86%[&]	87%

* Number of pedestrians observed. [&]p<0.05 in comparison with before period, chi-square tests.

4. Discussion and conclusions

This study examined the effect of a new road safety measure not yet employed in Israel – adding zigzag road markings on an urban road to warn drivers on approaching a marked midblock crosswalk. For this purpose, changes were examined in driving speeds when approaching the crosswalk, in giving right-of-way to pedestrians by vehicles at the crosswalk and in pedestrian behaviors when crossing, by comparing the behavior indicators after the introduction of the measure with the before period.

The findings showed that, in the short term (two weeks after the measure's introduction), a positive effect on driving speeds when entering the crosswalk approaching zone was observed at all study sites: a decrease of 9%-16% in average speeds on the dual-carriageway road and of 11% on the two-lane road. Two months later, a significant decrease in average speeds (of 7%-8%) related to the before period, remained at the dual-carriageway road sites, only. Yet, at one of the comparisons-sites (without zigzag marking), a decrease in travel speeds was also observed, in this period. In general, the relative reduction in travel speeds upon entering the approach zone between the study sites and the comparison-sites was observed only in the short term but not after two months. Furthermore, no effect of the measure was found on vehicle speeds near the crosswalks and in the situations when pedestrians were not present.

Regarding the rate of giving-way to pedestrians at the crosswalks, a substantial increase was observed at the dual-carriageway road sites, in both after periods, with the extent of relative change of 19%-20% in the short term and of 13%-14% in the longer term; however, at the two-lane street site, no significant change was found. At all treated sites, changes in pedestrian crossing behaviors were minor and inconsistent, indicating that, in general, no undesired changes occurred.

Overall, the study showed that zigzag road markings may improve pedestrian crossing conditions and promote pedestrian safety at midblock crosswalks. The effects were more tangible for dual-carriageway road sites than for the two-lane road, while the speed effect decreased over time. Unlike the US study (Dougald et al., 2012), this study's findings do not support a long-term impact of zigzag marking on travel speeds. At the same time, similar to previous research (Wilson, 1974; Dougald et al., 2012), the main effects of the measure were observed when pedestrians were present on the crosswalk. Among possible explanations for a weaker influence of the measure in the current study can be suggested the “novelty effect” of zigzag marking that increased drivers’ vigilance in the crosswalk area in the short term but was ignored later. In addition, it can be related to possible fading or blackening of the markings after two months at place, which might reduce its prominence and the consequent influence on drivers’ behavior.

The study findings were reported to the Ministry of Transport in Israel. Due to inconsistency of the results, which were apparently site-sensitive, and the over-time decrease of the safety-related effects, zigzag marking near pedestrian crosswalks was not recommended for wide use in the country. However, being aware of positive experience with this measure in other countries (Wilson, 1974; Department of Main Roads, 1988; Ribbens, 1996; Mutabazi, 2010; Dougald et al., 2012), future research would be useful to define local road and traffic conditions, in which zigzag markings would provide higher and more stable safety impacts, with a stronger potential for improving pedestrian safety at midblock crosswalks.

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