

AN EVALUATION OF CROSSWALK WARNING SYSTEMS

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A field experiment with a new type of uncontrolled pedestrian crossing is presented. The type includes systems for detecting pedestrians near the crosswalk zone and for warning drivers on pedestrian presence, by means of flashing lights embedded in the pavement adjacent to a marked crossing. The study aims to evaluate the safety impact of the device, through the consideration of changes in road user behaviour after system installation, and also to examine the operation under field conditions. Two variants of the device were involved, ARMS and Hercules, where each device was installed at two urban locations. The findings are that, under certain conditions, the system can bring about a reduction in vehicle speeds near the crosswalk zone; an increase in the rate of giving way to pedestrians; a significant reduction in vehicle-pedestrian conflicts in the crosswalk zone - to a rate of less than 1%; a reduction in the share of pedestrians crossing outside the crosswalk area - up to 10%. No improper influence of the system on keeping to safe crossing rules by the pedestrians, was found. However, both variants of the system did not prove themselves technically as ready for operation under field conditions.

According to most findings, ARMS demonstrated a positive influence on road user behaviour in the crosswalk zone whereas, to Hercules, the need for an additional testing period was established. Based on the study results, road and traffic conditions for the system's implementation were recommended.

Keywords: Pedestrian Crossing, Crosswalk Warning System, Road User Behaviour

Uncontrolled pedestrian crossings frequently present problematic locations in urban road network as having a potential for creating conflicts between pedestrian and vehicular flows (1). According to the law in most countries, on such a crossing a driver must give the right of way to the pedestrian but in practice many drivers do not behave in such a way. These crossings are associated with such events as drivers not noticing a pedestrian in the crosswalk area; drivers disregarding the crossing area and continuing at a high speed; lack of possibility for a pedestrian to cross the road during a period of intensive vehicular traffic, etc. To diminish the potential of conflicts with possible negative safety implications, some measures can be applied, such as an improving the general visibility conditions in the crosswalk area (2), erecting road humps in the crossing approaching zone or warning the driver about pedestrian presence in the crosswalk. The latter idea is implemented in crosswalk warning systems - a new type of uncontrolled pedestrian crossing, elements of which are presently developed in different countries (*e.g.* 3). A wide-scale experimental study with one of them, the LightGuard System, was recently carried out in California (4). To note, in the United States and some other countries the crosswalk warning system is sometimes known as a “flashing crosswalk” or “in-pavement flashing lights”.

In this paper the results of a field experiment with two other types of the crosswalk warning systems are presented. The systems tested in the current study were: type ARMS (Active Road Marking System for Road Safety), a product of Dalmark Technology Ltd – an Israeli startup company; and type Hercules, a modified product of Traffic System Corp., California, which is represented in Israel by IPI Ltd. Each type includes a pedestrian detection system, activated by sensors installed on low poles on both sides of the crosswalk, and a series of flashing warning light units which are embedded in the pavement adjacent to a marked crossing (Figure 1). The sensors detect a pedestrian standing/ entering a crosswalk waiting zone and activate the warning lights which are raised above the pavement and while flashing, send a bright beam of light towards oncoming vehicle traffic and, this way, inform the approaching drivers that a pedestrian is present on the crosswalk. The basic system flashing time depends on the road width and the average pedestrian speed. This basic value is gradually extended when several pedestrians consecutively cross the road. The types are similar in the operating principles but differ in the technological solutions applied: (a) as warning lights, ARMS uses standard raised pavement markings with LEDs inside, whereas

for Hercules a special technology for light installation in the pavement is developed which uses airfield lighting fittings; (b) ARMS recognizes the direction of a pedestrian crossing and activates the lights only once, when a pedestrian enters the crosswalk, whereas the Hercules reacts twice, when a pedestrian enters and leaves the crosswalk zone. Besides, within ARMS the light is emitted only on the side of oncoming vehicular traffic while in Hercules the lights radiate to both the oncoming traffic and towards the pedestrians.

It is expected that crosswalk warning systems will contribute to pedestrian safety, by emphasizing a pedestrian presence in the crosswalk zone and an earlier realization by the driver that he has to slow down and enable a pedestrian to cross the road. Thus, the purpose of this study was to evaluate the safety influence of the crosswalk warning systems, through the changes observed in road user behaviour in the crosswalk zone. Being relatively new, the systems had limited experience of implementation and no strictly determined criteria of performance; hence, the Israel Ministry of Transport, which supervised the experiment, decided to extend the project, involving two systems instead of one. The extension was aimed at providing background information for more general conclusions as to future system implementation and, also, at comparing the types' performance in field conditions.

METHOD

The study included an after/before comparison of road users' behaviour indicators, at the test sites.

Test Sites

Four typical problematic locations of uncontrolled pedestrian crossings in urban area were chosen as test sites. These sites were situated in the street sections with a relatively high concentration of pedestrian accidents and, also, were characterized by intensive pedestrian traffic during several hours a day. At the same time, the overall site characteristics did not yet satisfy the criteria for installation of a traffic signal controlled pedestrian crossing. Each location has a separation between the travel directions and the observations were focused on one half of crosswalk, with one vehicle direction and two directions of pedestrian traffic. The study sites were:

Site 1 – Moriah Street, Haifa City; a two-lane crosswalk on a central city artery, with a range of 30-180 pedestrians and 600-1700 vehicles per hour, during the day. The crosswalk is

situated after a road curve that limits the visibility conditions for both drivers and pedestrians.

Site 2 – Rothshield Boulevard, Haifa; a two-lane crosswalk on a downtown artery, in the vicinity of a shopping area, with 120-500 pedestrians and 400-1100 vehicles per hour, during the day.

Site 3 – 98 Balfur Street, Bat Yam City; a two-lane crosswalk with 100-300 pedestrians per hour;

Site 4 – 108 Balfur Street, Bat Yam City; a three-lane crosswalk with 50-300 pedestrians per hour. Sites 3 and 4 are on a busy commercial street, with 400-700 vehicles per hour, during the day. The street has a bi-directional bus lane in the middle, which is fully separated from other traffic along several segments of the street. Both lanes of site 3 and the two right lanes of site 4 are in use by all vehicle types whereas the left lane of site 4 is for bus traffic only (not separated).

The above estimates of traffic volumes were attained during the field observations. During daytime, the right lanes of the location streets were frequently occupied by parking vehicles that limited the data samples collected for these lanes. The ARMS system was installed at sites 1 (Photo 1,a) and 2, the Hercules system – at sites 3 (Photo 1, b) and 4.

Behaviour Indicators Considered

When the safety impact of a device/ system cannot be measured directly during a trial, a number of behavioural characteristics are usually chosen to serve as indicators of the influence examined. Based on the experience accumulated in observational studies of road user behaviour at pedestrian crossings (1,4,5,6) and aiming at a comprehensive picture of driver-pedestrian interaction at the locations tested, the following indicators were considered during the study:

- vehicle speeds;
- giving right of way to pedestrians;
- conflicts in driver-pedestrian interaction;
- pedestrians crossing the road outside the crosswalk area;
- keeping to safe crossing rules by the pedestrians.

Speeds were observed separately for cars (private and commercial) and buses, and for each lane (truck traffic is very limited in central urban areas). Both free vehicle speeds (some 30 m from the crosswalk) and speeds near the crosswalk were measured. The measurements

were carried out for most of the vehicles traveling through the section: depending on the density of the traffic volume, a record was made for each vehicle, or at a constant pace - 2-4 measurements per minute. Giving right of way to a pedestrian by the driver was considered in three situations: 1 – when a pedestrian is still on the sidewalk; 2 – when a pedestrian is already on the road, at the beginning of a crosswalk; 3 – when a pedestrian is in the middle of crossing. A vehicle-pedestrian conflict was defined as an abrupt change of course or speed by one of them, in order to avoid a collision (this definition is similar to encounters accepted by 5, 6). Pedestrians which are crossing the road outside the crosswalk area were counted within the road areas, 5-30 m before and after the crosswalk zone. According to expectations, a system implementation would result in a decrease in speeds, an increase in giving a way to pedestrians and in diminishing conflicts and pedestrian crossings outside the crosswalk area.

As accepted in safe pedestrian behaviour, before crossing a road, a pedestrian is supposed to stop and to observe the oncoming vehicle traffic. Keeping to these rules by pedestrians was considered in several situations of vehicle traffic: while no vehicle is oncoming on the road; when a vehicle is approaching the crosswalk on the lane close /far to a pedestrian; when there are oncoming vehicles in both lanes. In contrast to other indicators which can be directly associated with the system's operation, this indicator was dictated by the need to reject a suspicion, expressed by some authorities, that the system might give pedestrians an illusion of protection and makes them less careful while crossing the road. As stated by the developers, the systems demand no change in the usual rules of road users' behaviour on an uncontrolled pedestrian crossing. Thus, the level of keeping to safe rules by the pedestrians at the test sites was supposed to check the validity of this statement.

Field Observations

At each site, the study was planned to include three rounds of field observations: round 1 (baseline) – before the system installation; round 2 – several weeks after the installation; round 3 – several months after the installation. As no control sites were involved in the study, two “after” rounds were supposed to reveal some sustained effects of the system implementation, if those existed.

At each site, the observation round lasted 6-8 hours of a regular weekday (in regular weather conditions, mostly - sunny), including rush and non-rush hours of morning, day and evening that actually required 13-14 hours of presence at a site. Five observers were involved in each round: two were responsible for speed measurements, by means of a police speed-

gun, and also for traffic counting, at the end of every hour of observations; the third observer – for registration of vehicles' reactions (giving way) each time when a new pedestrian intended to cross the road; the fourth – for recording the actions of each pedestrian (whether he stopped; whether he observed the oncoming traffic) before a crossing and also, for counting of pedestrian traffic (within the crosswalk area) at the end of every hour; the fifth – for counting conflicts in vehicle-pedestrian interaction (successively, for half an hour) and for counting the number of pedestrians which crossed the road outside the crosswalk area (successively, for another half an hour). As introduced in the previous section, the recorded data included also relevant indications of road lane and type of vehicle (for speeds), of pedestrian placement before a crossing (for giving way), direction of pedestrian crossing, etc.

As to giving way observations, whose performance is not so obvious, the following technique was applied. An observation was made when a “new” pedestrian (or a group of) intended to cross the road, i.e. the crosswalk area was free or occupied by vehicles only. A reaction of vehicles which, at that moment, were at the “reaction distance” (3 meters or more) was recorded. Actually, the observer wrote down whether no vehicle was approaching the crosswalk, or counted the number of vehicles which did not yield the pedestrians. When this number differed from zero, the situation was later classified as “vehicle does not yield” (see “Analysis”).

The sample sizes collected were of more than 100 vehicles and about 50 pedestrians - for every behaviour observed, per hour of observations at each site. Due to operational problems with the installation and maintenance of the Hercules system, only one “after” round of observations took place on sites 3 and 4, about two months after the system activation.

Analysis

The data collected were handled for each round and after-before comparisons of indicators were performed, first, for each experimental site and, then, an overall consideration of changes through all the study sites, was carried out.

For site speed data to be compared under similar traffic conditions, the speeds observed in a specific lane were grouped in accordance with the categories of hourly traffic volumes which were observed over the study rounds. In each case (for a site lane, car/bus, free/ near the crosswalk speed), depending on available statistics, 1-4 categories of traffic

volumes and the same amount of speed samples, were arranged. Within each volume category, the mean speeds were compared between the rounds 2, 3 and the round 1.

The "giving way" data, for a site, were arranged according to the three pedestrian positions (i.e. "a pedestrian on the sidewalk", "a pedestrian at the beginning of the crosswalk", "a pedestrian in the middle of crossing") so that three series of hourly "giving way" rates were provided for each observation round. In general, one of three situations is possible when a pedestrian, in any position, is crossing the road: (a) no vehicle approaches the crosswalk; (b) the vehicle yields to the pedestrian; (c) the vehicle does not yield. The hourly "giving way" rate is calculated as a share of "b"-situations out of the total number of situations "b" and "c". The average "giving way" rates (for the three pedestrian positions), obtained in the "after" periods, were compared with the relevant rates for the "before" period.

The conflict data and the number of pedestrians crossing "outside", for a site, were presented as hourly numbers and the hourly rates were calculated as opposed to corresponding pedestrian traffic volumes (within the crosswalk area). The average conflict rates and the rates of pedestrians crossing the road before and after the crosswalk, were compared between the "after" and "before" rounds of observations.

As to keeping to the pedestrian rules, the hourly rates of proper behaviour (a share of those who stopped and a share of those who looked at the oncoming traffic) were calculated, for a specific site, direction of crossing and a defined situation of vehicle traffic ("no vehicle oncoming on the road"; "a vehicle approaching on the near lane", etc.). The relevant average rates (for each road situation and direction of travel) were compared between the "after" and "before" observation rounds.

As the possibility that changes in vehicular and pedestrian traffic in the after period as opposed to the before, could influence road user behaviour, the consideration of behavioural indicators was preceded by a comparison of values of traffic volumes which were observed in both periods. For this, a scattering of pair values (the vehicular and the pedestrian traffics in the same hour) in the rounds 2, 3 was compared with the corresponding values of the round 1. As found, no significant change occurred in most cases, except for a slight decrease in the vehicular traffic on site 2, during the round 3.

RESULTS

Site-specific results

Table 1 reports the results of speed changes observed at the study sites. Table 2 shows changes in the rates of giving way to pedestrians, in the vehicle-pedestrian conflict rates at the crosswalk zone and in the rates of pedestrians which crossed the road outside the crosswalk area. (In all the cases, the changes were accepted as significant with $p < 0.05$.) It can be seen that following the installation of the systems:

On site 1- most vehicle speeds, both free and near the crosswalk, decreased where the majority of these changes was statistically significant; the rate of giving way to pedestrians improved in the two situations of beginning a crossing (mostly, significant, in both “after” rounds) but somewhat decreased in the third situation when a pedestrian is in the middle of the crossing (not significant); both the rate of conflicts and the rate of crossings outside the crosswalk area decreased considerably: the former from 17 percent to less than one, the latter - from more than 100 to about 15 percent (both changes are significant).

On site 2 - most vehicle speeds, both free and near the crosswalk, decreased and the majority of changes was statistically significant; all the rates of giving way increased in round 2, immediately after system installation, the rate in the situation when a pedestrian is still on the sidewalk improved even after whereas the rates in the two other situations (a pedestrian at the beginning or in the middle of a crossing) diminished after a period but still were higher than before system installation (most changes are not significant); the rate of conflicts at this site was and stayed low – less than one percent; the rate of crossings outside the crosswalk area decreased slightly in round 2, from some two to one percent, but demonstrated a significant jump to some five percent, in round 3.

On site 3 – an increasing trend was seen in most bus speeds and in the car speeds in the right lane but the majority of changes was not significant; all the rates of giving way to pedestrians increased where in two situations of three (a pedestrian on the sidewalk or in the middle of a crossing) the changes were statistically significant; the rate of conflicts decreased from some two to zero percent and the rate of “outside” crossings – from about 22 to 9.5 percent (both changes are significant).

On site 4 – in most cases with larger data samples (e.g. left lane car speeds, bus lane speeds) a decreasing trend was seen in speeds but the majority of changes was not significant; an increasing trend appeared in two giving way rates (when a pedestrian at the beginning or in the middle of the crossing) and a decreasing one – in the third situation (a pedestrian on the sidewalk), but none of the changes was significant; the rate of conflicts changed from one to

zero percent (not significant); the rate of crossings outside the crosswalk area decreased significantly, from about 50 to 10 percent.

Concerning site 4, caution is needed in interpreting the results because during the third hour of observations in round 2, a truck hit one of the site system detectors and the system lights began flashing continuously. To accomplish the observations, the observers moved to another half of the crosswalk. In general, one can observe that the same pedestrian and vehicle populations were involved in both parts of the round; in addition, as examined, the behaviour changes found were similar across different hours and directions of crossing. Nonetheless, the comparison conditions in this case are less “clear” and the changes observed on site 4 should be given a lower weight than those observed on other sites.

Summary of changes

As demonstrated, the behaviour changes observed at the study sites were not uniform which reflected the differences between the site conditions and, possibly, between the system types studied. An overall consideration of the results was believed to assist in answering some practical questions such as introducing numeric values of the system influence on road users’ behaviour, recommending traffic conditions favourable for system implementation and a comparison between the types’ performance.

Table 3 summarizes the average values of behaviour indicators which were attained in round 1 (“before”) and in rounds 2, 3 (“after”). In a similar way, Table 4 describes the trends of changes, where A denotes “a significant improvement was observed in most cases of the set”; B – “an improvement trend, in all the cases”; C – “a significant improvement was found in part of cases but also a worsening trend in a minority of cases”; D – “a mixed trend, no significance”; E – “a general worsening trend”. Thus, the above ranks cover all the variants of changes observed where going from A to E corresponds to a weakening of a desired trend of changes. Overall, the ranks A-C can be interpreted as *an improvement* in the behaviour considered whereas the ranks D-E corresponds to *a lack of improvement*. Based on Tables 3, 4, the following summary findings can be derived as to the crosswalk system influence on road users’ behaviour:

- both free speeds and the speeds near the crosswalks, decreased after the system installation on the sites 1, 2, whereas on the sites 3, 4 a mixed trend of changes was observed and the speeds actually did not change. With a certain caution, it can be concluded that the system can bring about a decrease of 2-5 kph in average vehicle speeds

- in the crosswalk zone, however, apparently only at sites where the initial speeds are higher than 30 kph. On sites where both free and near the crosswalk vehicle speeds are lower than 30 kph, the system is incapable of bringing about an additional reduction in speeds;
- overall, there was a positive change in giving way to a pedestrian at sites 1-3 while at site 4 the picture was unclear. At sites 1-3 the system brought about a doubling of the rate of giving way to a pedestrian, in the situations of beginning a crossing and this rate reached 40 percent at sites 1, 2. As to the same index in the situation of “in the middle of crossing by a pedestrian”, the system did not contribute to a systematic improvement of its value, on sites 1 and 2, where a 70 percent rate of giving way appears to be a natural “point of equilibrium”. An extremely high value of the last index at sites 3, 4, probably, stems from a complex traffic situation on this street (the integration of a bus lane);
 - across all the sites studied the system diminished the rate of conflicts in the crosswalk area to a negligible, less than one percent level. The improvement was especially remarkable at site 1 where this rate was high before system installation;
 - it appears that the system attracts the pedestrians to cross the road on a “legal” crosswalk as a significant reduction in the share of crossings outside the crosswalk area was observed at three sites out of four. Again, the improvement was especially recognizable at site 1 where, before system installation, some half of the pedestrians crossed the road outside the crosswalk area. Overall, the system seems to have a capability to reduce this rate up to 10% but not to neutralize the phenomenon completely. The latter was indicated in the behaviour observed at site 2 where the index was low in the “before” period and demonstrated inconsistent changes in the “after” period. At this point, it is worth mentioning that pedestrians who enter the road outside of the crosswalk would not activate the flashers. Perhaps, some pedestrians are attracted to cross within the crosswalk so that they will activate the flashers and therefore benefit from the system.

As to the changes observed in keeping to safe crossing rules by the pedestrians, most of them were insignificant (7). Across all the sites, a slight increasing trend was found in the rate of pedestrians which looked towards oncoming vehicle traffic, before a crossing; however, overall, this rate was and stayed within 0.9-1 limits, for all the situations of vehicle traffic (“no vehicle oncoming on the road”; “a vehicle approaching in the near lane”, etc.). The rate of pedestrians who stopped before a crossing changed between the rounds, with no regular trend according to location (sites 1, 2 as opposed to sites 3, 4) or traffic situation. In general, the rate of stops before a crossing was and stayed about 0.4-0.5, in the situation

when no vehicle was oncoming on the road, and varied between 0.5-0.9, in the remainder of cases. Hence, no improper influence of the system on keeping to the crossing rules by the pedestrians, was identified.

DISCUSSION AND CONCLUSIONS

Results demonstrate that crosswalk warning systems have a potential of positive influence on vehicle-pedestrian interaction in the crosswalk area. Under certain conditions, the system's introduction can bring about a reduction in vehicle speeds near the crosswalk zone; an increase in the rate of giving way to pedestrians; a significant reduction in the conflict rates; and a reduction in the share of pedestrians crossing outside the crosswalk, whereas the pedestrians, in general, keep to the same crossing rules as before. Most behaviour changes lasted for several months after the system installation.

The findings are comparable with (3) who found that at different sites, the installation of a crosswalk warning system (another type) was associated with an increase in giving way to pedestrians to a level of 30-90 percent, and that the pedestrians seemed to be continuing to cross the street with the same level of caution as before.

Concerning the behaviour changes associated with specific system types, it can be concluded that

- the installation of system ARMS (at sites 1 and 2) was followed by positive changes in most behaviours such as a reduction in both free and near the crosswalk vehicle speeds; an increase in giving way to a pedestrian, mainly in situations of beginning a crossing; a drastic reduction in the conflict rate in the crosswalk zone and a diminution of the rate of pedestrians crossing outside the crosswalk area. As a whole, it is concluded that type ARMS proved its positive influence on road user behaviour in the crosswalk zone (7).
- The installation of system Hercules brought about positive changes in giving way to pedestrians, both at the beginning and in the middle of crossing; a decrease of conflicts in the crosswalk zone and a reduction of crossings outside the crosswalk area. At the same time, no regular changes in the vehicle speeds near the crosswalk area were identified. Also, the rate of giving way to pedestrians, in spite of the increase attained, stayed relatively low. It is possible that less clear behaviour changes associated with this type can be partly explained by the complex traffic conditions on both sites tested. Besides, due to various operational problems of the system, the "after" period of observations was shorter

than for the ARMS type. In general, to provide a basis for firmer conclusions as to the system safety influence, the need for an additional testing period was established (7), and this should take place under more regular traffic conditions.

As to the systems' technical performance, both types studied did not prove themselves as ready for operation under field conditions. The ARMS type was installed according to schedule and functioned properly at both sites at least during the initial period of several months. Later, vandalism harmed normal system operation whereas the producer company not always was fast in eliminating malfunctions. The system ceased to function correctly because of severe weather – pouring rains during winter. The Hercules system had operational problems over the whole study period: the installation was delayed for several months; even during the initial “after” period the devices worked intermittently; the occasional field tours revealed different malfunctions in system operation. On the whole, the devices' technical disfunctions during a significant part of the study period, harmed both the study conclusions and the systems' perception by the road users and by the local authorities who supervised the study.

Based on the study findings, the following conditions can be recommended for achieving potential benefits of the system's implementation.

One. The crosswalk warning system seems suitable for sites with uncontrolled pedestrian crossings, i. e. on those where a marked crossing already exists but which do not satisfy the demands for installing traffic lights.

Two. The system is intended for road sections and not for junctions to avoid possible confusion with other traffic control devices.

Three. The system suits installation on urban arteries and city centers.

Four. The locations warranted the installation are those where 1) average vehicle speeds, both free and near the crosswalk, are over 30 kph; and 2) the rate of giving way to pedestrians is low; and 3) during the day hours, either there is an intensive pedestrian flow through the crosswalk; or there is a less intensive pedestrian flow but the site is also characterized by a high rate of conflicts in the crosswalk zone or a high share of pedestrians crossing outside the crosswalk area. (The intensive pedestrian flow can be defined as in (8) which, for a street section, requires over 160 pedestrians per hour, during eight hours of observations.)

The current study did not relate to the application of crosswalk warning systems at locations with low pedestrian flows; recommendations relevant to such sites can be found in (3).

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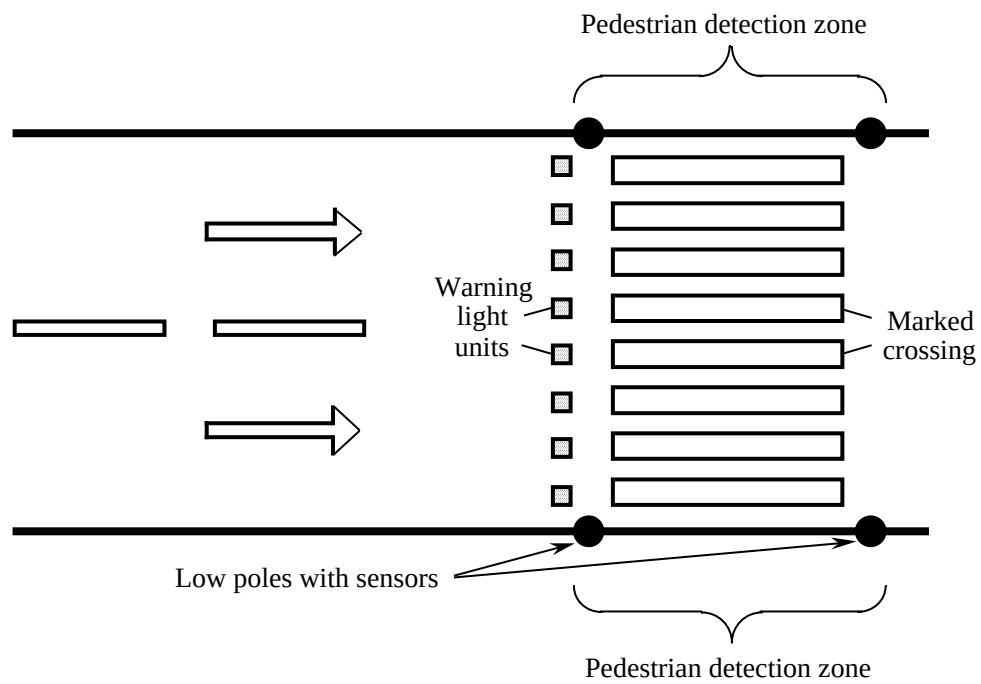


Figure 1. Components of crosswalk warning system.



a



b

**Photo1. Crosswalk system installation at the study sites:
a - site 1 (the ARMS system); b - site 3 (the Hercules system).**

TABLE 1 Speed Changes Observed at the Study Sites

Site	Place of measurement	Results, per lane and vehicle type	Right lane, Car				Left lane, Car			Right lane, Bus	Left lane, Bus	
1	Free speeds	HTV ^a	<300	300-400	>400		<500	500-700	>700	All	<700	>700
		Average speeds ^b , Round 1	35.0	29.8	34.6		38.3	35.4	37.0	30.5	33.1	24.2
		Average speeds ^b , Round 2	22.3**	25.2*	25.1**		34.0**	25.8**	30.7**	19.5	20.2**	20.4
		Average speeds ^b , Round 3	31.6	14.8**	22.5**		35.9	28.1**	27.5**	24.1	23.6**	23.7
	Near the crosswalk speeds	HTV ^a	<300	300-400	>400		<500	500-700	>700	All	<700	>700
		Average speeds ^b , Round 1	31.4	30.3	30.7		32.0	34.0	28.8	28.9	32.0	29.2
		Average speeds ^b , Round 2	32.7	25.7	24.0		28.1*	26.9**	30.7	22.2	27.6	21.4*
		Average speeds ^b , Round 3	28.3	14.1**	18.5**		30.8	31.1	24.1**	20.4	27.0	22.8*
2	Free speeds	HTV ^a	<300	300-400	400-500	>500	<300	300-400	>400	All	<400	>400
		Average speeds ^b , Round 1	39.7	33.5	29.3	34.8	43.0	42.8	36.4	33.0	41.7	37.8
		Average speeds ^b , Round 2	n/a	32.3	29.8	29.1**	33.9**	38.4	35.3	31.5	41.2	32.7**
		Average speeds ^b , Round 3	33.0**	32.1*	n/a	n/a	35.1**	38.4*	n/a	32.3	35.5*	n/a
	Near the crosswalk speeds	HTV ^a	<300	300-400	400-500	>500	<300	300-400	>400	All	<400	>400
		Average speeds ^b , Round 1	37.9	33.9	30.1	31.8	41.4	38.1	35.9	32.4	42.2	37.6
		Average speeds ^b , Round 2	n/a	33.7	24.4**	27.7	33.2*	34.8	30.3**	28.3	35.0**	27.3**
		Average speeds ^b , Round 3	33.6**	26.1**	n/a	n/a	37.3*	33.6*	n/a	29.9	35.7**	n/a

^aHTV - hourly vehicle traffic, vehicles per lane^bSpeeds are given in km per hour

* Comparison with Round 1 is significant at the 0.05 level

** Comparison with Round 1 is significant at the 0.01 level

TABLE 1 (cont.)

Site	Place of measurement	Results, per lane and vehicle type	Right lane, Car		Left lane, Car		Right lane, Bus		Left lane, Bus	
3	Free speeds	HTV ^a	<500	>500	All		<500	>500	<500	>500
		Average speeds ^b , Round 1	26.7	24.0	29.2		23.6	21.3	27.9	26.7
		Average speeds ^b , Round 2	28.0	23.8	25.3		24.4	23.4	27.4	29.6
	Near the crosswalk speeds	HTV ^a	<500	>500	<500	>500	<500	>500	<500	>500
		Average speeds ^b , Round 1	24.0	22.5	23.2	24.4	20.3	21.0	22.7	21.9
		Average speeds ^b , Round 2	24.3	24.9**	24.3	22.5	23.7	20.1	23.3	26.8**
4 ^c	Free speeds	HTV ^a	All		Morn	Eve	Morn	Eve	Morn	Eve
		Average speeds ^b , Round 1	25.4		29.8	29.6	26.7	26.7	29.0	27.8
		Average speeds ^b , Round 2	28.2		28.0*	25.8**	24.6	25.2	27.9	28.9
	Near the crosswalk speeds	HTV ^a	All		Morn	Eve	All		Morn	Eve
		Average speeds ^b , Round 1	16.7		19.5	19.0	16.7		18.8	16.6
		Average speeds ^b , Round 2	18.1		18.6	18.3	17.4		16.0*	15.6

^aHTV - hourly vehicle traffic, vehicles per lane

^bSpeeds are given in km per hour

^cAt site 4 bus speeds, instead of right and left lanes, are given for left and bus lanes, accordingly. At this site, no bus traffic in the right lane and no car traffic in the bus lane were observed. Besides, all hourly traffic volumes at this site were within 400-600 vehicles per lane, thus the speed samples could not be arranged in accordance with the categories of traffic volumes; when available, morning and evening hours of observations were grouped.

* Comparison with Round 1 is significant at the 0.05 level

** Comparison with Round 1 is significant at the 0.01 level

TABLE 2 Changes in Other Behaviours Observed at the Study Sites

Site	Round of observations	Rate of giving way to pedestrian, when a pedestrian is			Rate ^a of vehicle-pedestrian conflicts in the crosswalk area	Rate ^a of pedestrian crossings	
		on a sidewalk	at the beginning of crosswalk	in the middle of crossing		before the crosswalk zone	after the crosswalk zone
1	1	0.18	0.20	0.82	0.169	0.544	0.490
	2	0.49*	0.44*	0.65	0.004**	0.145*	0.019**
	3	0.35*	0.31	0.70	0.006**	0.099*	0.012**
2	1	0.11	0.32	0.60	0.010	0.018	0.003
	2	0.27	0.51	0.85	0.004	0.011	0.002
	3	0.34**	0.37	0.67	0.007	0.022	0.026*
3	1	0.11	0.13	0.55	0.017	0.209	0.010
	2	0.25**	0.26	1.00**	0.000*	0.033**	0.062
4	1	0.13	0.05	0.80	0.009	0.089	0.408
	2	0.08	0.15	0.97	0.000	0.017*	0.086*

^a The rates are estimated as opposed to pedestrian traffic volumes within the crosswalk area.

* Comparison with Round 1 is significant at the 0.05 level

** Comparison with Round 1 is significant at the 0.01 level

TABLE 3 Summary of Average Values of Behaviour Indicators at the Study Sites, Before and After System Installation

Site	Free speeds ^a , kph			Speeds near the crosswalk ^a , kph			Giving way to pedestrian ^b			Rate ^c of conflicts in the crosswalk zone			Rate ^c of pedestrian crossings outside the crosswalk zone		
	Before (round 1)	After (round 2)	(round 3)	Before (round 1)	After (round 2)	(round 3)	Before (round 1)	After (round 2)	(round 3)	Before (round 1)	After (round 2)	(round 3)	Before (round 1)	After (round 2)	(round 3)
1	33	24	26	31	29	23	19%	46%	33%	17%	less than 1%	less than 1%	103%	16%	11%
	37	30	29	31	28	27	82%	65%	70%						
	29	20	24	30	26	22									
2	34	30	33	34	28	32	22%	39%	36%	1%	less than 1%	less than 1%	2%	1%	5%
	40	36	36	38	32	36	60%	85%	67%						
	38	35	35	38	31	35									
3	25	26	n/a	23	25	n/a	12%	25%	n/a	2%	0%	n/a	22%	10%	n/a
	29	26		24	23		55%	100%							
	26	27		22	24										
4	29	27	n/a	19	18	n/a	9%	12%	n/a	1%	0%	n/a	50%	10%	n/a
	28	27		17	16		80%	97%							

^aFor each site, rows describe: car speeds in the right lane, car speeds in the left lane and bus speeds in both lanes together, accordingly; except for site 4, for which car speeds in both lanes and bus speeds for all lanes together, are presented.

^bFor each site, rows describe: rates of giving way to a pedestrian at the beginning of crossing (a combination of “on a sidewalk” and “at the beginning of crosswalk” positions) and in the middle of crossing, accordingly.

^cThe rates are estimated as opposed to pedestrian traffic volumes within the crosswalk area.

TABLE 4 Summary of Trends of Changes in Behaviour Indicators at the Study Sites, After System Installation

Site	Round of observations	Free speeds ^a	Speeds near the crosswalk ^a	Giving way to pedestrian ^b	Conflicts ^b	Pedestrian crossings outside the crosswalk zone ^b
1	2	A A B B	D C B B	C	A	A
	3	A A B B	A B B B	C	A	A
2	2	C B B B	B A B A	B	B	B
	3	B A B A	A A B A	B	B	E
3	2	D B E D	E D D E	A	A	C
4	2	E A B D	E B E B	D	B	A

Where: A implies an improvement (mostly, significant); B - an improvement trend; C - an improvement (significant) but also a worsening trend; D - a mixed trend (insignificant); E - a general worsening trend.

^aEach symbol represents a set of speeds considered, e.g. car speeds in the right lane, car speeds in the left lane, etc. - see Table 1.

^bEach symbol represents a set of values reported in Table 2.