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The Evaluative Study For Improving Road Safety By Increasing The Visibility And Conspicuity Of Zebra Crossing Areas In Front Of Schools On Urban Roads

P. Jantosut
Department of Civil Engineering, Faculty of Engineering, Mahasarakham University, Mahasarakham, 44150, Thailand
Email: piyanat.j@msu.ac.th

P. Tankasem
Department of Civil Engineering, Faculty of Engineering, Mahasarakham University, Mahasarakham, 44150, Thailand
Email: phongphan.t@msu.ac.th

W. Chaipanha
Department of Civil Engineering, Faculty of Engineering, Rajamangala University of Technology Khon Kaen Campus, Khon Kaen, 40000, Thailand
wuttikrai.ca@rmuti.ac.th

P. Kaewwichian
Department of Civil Engineering, Faculty of Engineering, Rajamangala University of Technology Khon Kaen Campus, Khon Kaen, 40000, Thailand
Email: patiphan.ka@rmuti.ac.th

Promraksa
Department of Civil Engineering, Faculty of Engineering, Ubon Ratchathani University Ubon Ratchathani, 34190, Thailand

R. Kaewkluengklom
Department of Civil Engineering, Faculty of Engineering, Ubon Ratchathani University Ubon Ratchathani, 34190, Thailand
Email: rattanaporn.k@ubu.ac.th

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Abstract

This research was aimed at studying and evaluating the improvement of Safety of Zebra Crossings in front of Schools (SZCS) Project by increasing the visibility and conspicuity of the crossings situated in urban area in Khon Kaen Province, Thailand, during the pre- and during SZCS Project. The total study period was 18 months, and the scope of study was on 4 aspects: 1) vehicle speed, 2) degree of road safety for pedestrians based on iRAP standard, 3) traffic accidents in the Project area, and 4) worthiness of investment. The research on vehicle speed was carried out by dividing the zones: namely, before reaching SZCS, the zebra crossing point, and the zone after passing SZCS both during peak and off-peak hours. The degree of road safety was based on the scores and sums of different factors from iRAP studies. The worthiness of investment was found by analyzing the Benefits-Cost Ratio. The findings indicate the followings: 1) Speeds can be significantly reduced at the SZCS point during the first 3 months; however, after 12 months, the average speed slightly decreased with no statistical significance. 2) The traffic calming measure in the Project area could augment the pedestrian safety degree from 3-star to 4-star level. 3) The number and severity of road accidents decreased. 4) The SZCS Project requires a low budget and is worth investing. The findings demonstrate both the direct and indirect efficiency of the improvement of the zebra crossings by increasing their visibility and conspicuity in front of schools.

Keywords

zebra crossing, pedestrian, road safety, school, evaluation project

1. Introduction

Zebra crossings should be a safe zone for pedestrians, especially school students who belong to the most fragile group of road users. Nevertheless, it was found from road accident data of WHO that 26% of pedestrians and bicycle riders died each year from road accidents, where most cases occurred in low- and moderate-income countries [1]. The overall results of studies on pedestrians all over the world show that injuries and deaths occur from crashes during road crossing [2]. In Thailand, a lot of pedestrians are injured and died from road accidents each year. It was found, during the past 10 years, that there were 6,739 cases of death of pedestrians, or an average of 1.84 cases per day. The age range lower than 18 years or those at school age accounted for 100 cases per year, and the proportion is 1.23 deaths per 100,000 people. Most cases were the results of car crashes at the road crossing [3,4]. Over 50% were crashed by motorcycles [5]. The data shows the unsafety problem of pedestrians, particularly the children group. It can be seen that generally, roads in low- and medium-income countries including Thailand have principally been designed for benefits of vehicles. Construction of facilities and safety has been geared towards vehicle users. The concept of infrastructure development for a collective use of roads between vehicle drivers and pedestrians is the least of interest.

The important problem affecting the number and severity of road accidents is the fact that the high speed of vehicles increases the severity of injuries and death rates among pedestrians and bicycle riders involved [6,7]. The World Health Organization (WHO) advised car drivers to keep the speed at 30 kilometers per hour [1], while the surveys of low- and medium-income countries in Asia, Africa, Eastern Europe and Middle America show that 84% of vehicle drivers still use the speed over 40 km/hr. [8]. Therefore, speed management is among the first-priority measures in the solution of traffic accidents popularly carried out all over the world [1,9]. In Thailand in the recent past, there has been no law governing vehicles to use low speeds in urban areas or in areas with a lot of pedestrians. At present, the regulations have been changed by limiting speeds of those vehicles at 60 km/hr in urban or community areas [10,11]. The limited speed here is exceeding the recommended speed limitation by WHO, thus showing that road users, especially the pedestrians in Thailand, still face high risk from the regulations.

The favored safety measure for road safety at the crossing areas in Thailand stipulates the traffic lines on the crossing so that pedestrians and vehicle drivers can use the area safely. If a road crossing is crowded with road crossers such as in community or educational institution areas, traffic lights for road crossing or a warning sign should be installed [12] to warn vehicle users to be cautious in driving and reduce the speed to give way to pedestrian crossers [13]. However, the surrounding conditions at present are not perfect and lack maintenance. This may partly cause accident risks among road users, especially at school areas where road users are the most fragile group. Therefore, the objective of this research is to study and evaluate the improvement of road safety by increasing visibility and conspicuity for Safety of Zebra Crossings in front of Schools (SZCS). The budget for carrying out the research is not high and suitable for the economic condition and the context of road users in Thailand.

International Road Assessment Program (iRAP) is the widely used evaluating standards for the traffic lane conditions and for improving road safety. The methods anywhere in the world are in agreement, for they have been designed based on research studies and different technologies including expertise in road safety engineering. The basic attributes and structures used for evaluating road safety of iRAP are collected during the road investigation [14-16]. ViDA is an online program for calculating the Star Rating Scores (SRS) for evaluating the star levels of a road [17].

1.1. Literature Reviews

The information in the Table 1 shows that good zebra crossings must be based on different attributes rather than just being a zebra crossing for the safety of users.

Table 1: Research studies on road safety with effect on pedestrians

Authors	Related studies
[18-22]	Lane width and number affect drivers' speed selection.
[23]	Road width and distance of the crossing has negative influence on road crossing users. The road with elevated traffic island, one-way traffic, available parking space on the road, has opposite influence.
[22, 24-26]	Optical Speed Bars result in speed reduction of vehicles, but in some studies, the effect is stated to be in a short period.
[21, 27-30]	Safety, facilities, the crossing time of pedestrians, are important factors for decision to use the crossing. Zebra crossing brings about more users, reduces the waiting time for crossing and the crossing time, and users of the crossing feel safer and more confident.
[28,31]	Roads that are suitable for pedestrians must make drivers aware of the collective usage with children and elderly groups.
[32]	Violation of signs at the crossing usually occurs at dense traffic areas, resulting in longer waiting time. There is more chance for road users to violate regulations when there are a lot of pedestrians, and violation of crossing signs usually happen more during the morning peak hours than other periods.
[33]	Children crossings should be under guard of adults. Over two thirds of children do not look out for vehicles before crossing.
[34-37]	Advanced Stop Line increases scope of visibility for both road crossers and vehicle drivers.
[31, 34-35, 38]	Increasing visibility and clarity of signs and crossings makes road users take more precautions.
[14-16]	Improvement of physical characteristics and road ambientes should be based on iRAP standard. One level higher of Star Ratings results in 60% reduction of death and severe injury rates.

1.2. Safety of Zebra Crossings in front of the School Project (SZCS)

The review of related research on road safety at the zebra crossing areas in the country and abroad leads to improvement of the attributes of the zebra crossings in front of schools in urban areas. The key components are shown in Figure 1 and Figure 2.

At the SZCS Project sites implemented on 3 arterial roads, 13 schools are situated, as shown in Figure 3. Here, traffic problems were taken into account related to lack of clarity of zebra crossing attributes. For instance, the colors of traffic lines and zebra lines have faded, there is no sign to warn children when crossing, or the sign is damaged or at a point obstructed by other items, leading to accidents occurring to pedestrians. Five schools were selected for the Project study and were used as representatives for engineering evaluation. The budget for the Project was subsidized by the Safer Roads Foundation (SRF), England (39).

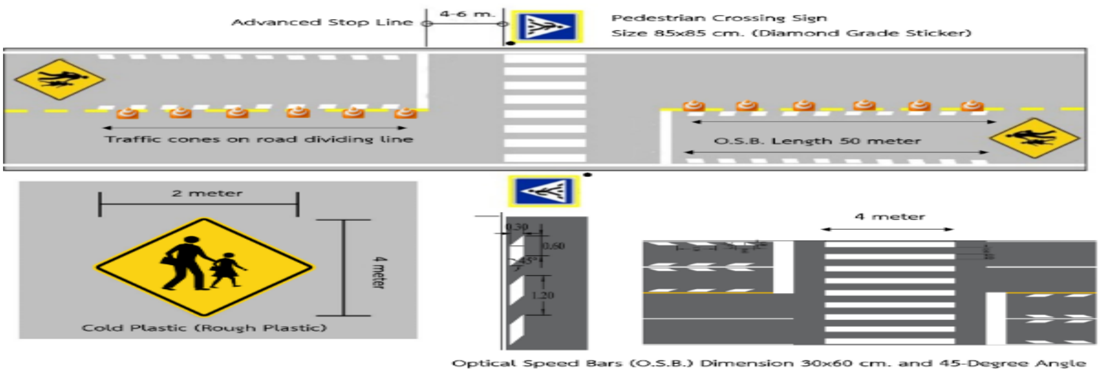

Figure 1: Components of zebra crossings implemented by SZCS Project

Figure 2: Example of 3-dimension pictures with zebra crossing attributes under SZCS Project at a study site

Figure 3: The study sites of SZCS Project

2. Methodology

2.1 Survey of Data

2.1.1 Basic Components of Roads

The researcher team conducted surveys of traffic amount during the morning peak hours and off-peak hours of the working days (32,40), when schools are opened. The physical data of road attributes were surveyed according to iRAP standard (14-16), for example, the form and type of traffic islands, number of traffic lanes, traffic management, area usage characteristics, etc.

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2.1.2 Vehicle Speed Surveys

The vehicles selected under this research for the evaluation analysis were cars and motorcycles. The person conducting the survey had to be positioned at the point unobservable by the road users and performed the survey from the back of the vehicle movement, so that there would be no influence on the change of behavior in speed selection. At the position of the surveyor, the researcher divided the area into 3 parts (as shown in Figure 4): 1) before entering the Project zone (roughly 100-150 meters from the center point), 2) the implemented area, and 3) beyond the implemented area. This survey was conducted at the same period of time as the survey on the amount of traffic.

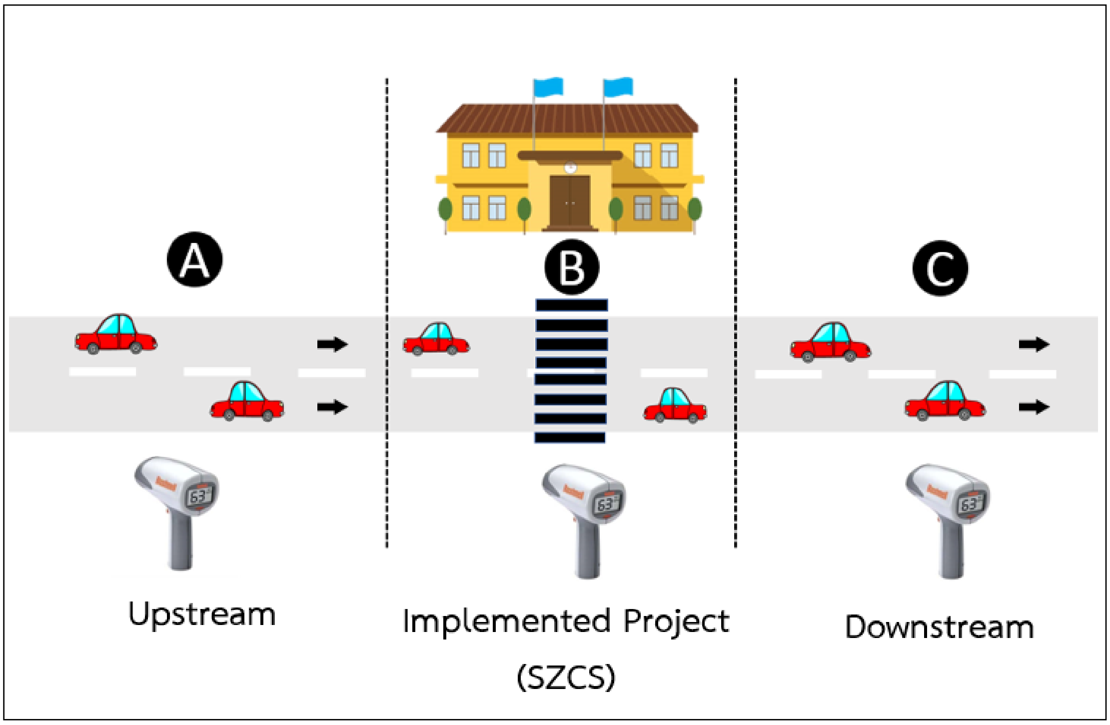

Figure 4: Positions of speed surveys

2.1.3 Compilation of Road Accident Data

The research team compiled the information on road accident data in the implemented areas from 2019 to 2022 from relevant departments and organizations (41).

2.2 Data Analysis

2.2.1 Baseline Data

The comparative analyses were performed on the information of the physical characteristics of the roads at the study sites and the amount of traffic of each period, before and during the Project, using the descriptive statistics.

2.2.2 Comparison of Vehicle Speeds

The speeds of both cars and vehicles were analyzed using the average parameters. Comparison was conducted between before and during the implementation at all 3 points, based on the Independence T-Test at a 95% confidence level between the pre-project and project periods.

2.2.3 Evaluation of Road Safety among Pedestrians Based on iRAP Standard

The data of different attributes from the surveys were evaluated using ViDA – Online software (17). Conclusion was made in scores and star levels of road safety rated by pedestrians, compared between the periods before and during the SZCS Project.

2.2.4 Evaluation of Road Accidents and Worthiness of Investment

A comparative study was conducted between the period before and during the Project to determine the worthiness of investment of SZCS. The worthiness was analyzed by the benefits-cost ratio, considered from the equivalence of the present years of the benefits from reduction of loss from road accidents in SZCS Project sites and the cost of construction of SZCS Project covering all related areas. The economic cost of road traffic accidents in Thailand totaled 1,649 dollars from slight injuries; 13,746 dollars from severe injuries, and 102,445 dollars from fatality (42).

3. Results

3.1 General Data

The results of the survey on the amount of traffic and road crossing users are shown in Table 2 and Table 3, respectively. The averages are found to be relatively similar, showing that the attributes have an influence on speed selection of vehicles at the study sites and the vicinity.

Table 2: Amount of traffic passing the study sites before and during project implementation

NO.	Schools	Averages (Vehicles/hour)		
		Morning peak hours	Off-peak hours	Evening peak hours
1.	Holy Redeemer Northeastern region School	2,463	1,997	2,260
2.	Khon Kaen Wittayayon School	4,240	2,758	2,547
3.	Kanlayanawat School	4,320	3,216	3,118
4.	Kaennakhon Wittayalai School	5,627	3,633	4,651
5.	Sotsuksa Khon Kaen School for the Deaf	5,295	3,004	4,397

Table 3: Number of pedestrians at the zebra crossing points before and during project implementation

NO.	Schools	Averages (Pedestrians/hour)		
		Morning peak hours	Off-peak hours	Evening peak hours
1.	Holy Redeemer Northeastern region School	290	52	194
2.	Khon Kaen Wittayayon School	264	21	276
3.	Kanlayanawat School	510	39	612
4.	Kaennakhon Wittayalai School	464	98	768
5.	Sotsuksa Khon Kaen School for the Deaf	42	12	50

3.2 Analysis of Average Speeds, before and during Project Implementation

The data demonstrate that the position with the lowest average speed is SZCS in all study sites (Table 4). The average speed during the off-peak hours is higher than the safety recommended speed for roads passing schools (30 km./hr.). At peak hours, the averages were found to be lower than the safety speed, which was influenced by the amount of traffic at the period. Figure 5 shows that the average speed 3 months after the Project began was higher and close to the average speed before the measures were taken.

Table 4: Comparative results of average speeds before and during the Project at each implementation period

NO.	Types	Average Speed (km./hr.)								
		Before			3 Months after			18 Months after		
		A	SZCS	C	A	SZCS	C	A	SZCS	C
1	PC	40.61	40.50	40.29	38.94	36.11	37.99	40.62	40.01	40.45
		28.53	26.90	27.78	26.84	24.85	25.64	28.11	26.75	27.58
	MC	42.50	42.30	42.67	40.91	40.08	40.54	42.41	42.15	42.64
		29.21	28.78	29.12	27.81	27.71	27.08	28.89	28.51	29.01
2	PC	37.04	37.14	37.99	36.54	34.74	36.46	37.21	36.63	37.49
		26.50	25.20	25.80	24.27	23.21	24.70	26.12	24.68	25.45
	MC	39.65	39.83	39.94	38.81	38.23	38.93	39.21	39.15	39.67
		27.30	26.60	26.20	26.64	25.72	26.11	27.11	26.45	26.28
3	PC	34.51	34.90	34.67	32.25	31.10	32.51	34.11	34.33	34.45
		26.20	25.10	25.62	25.11	23.13	24.24	25.78	24.75	25.42
	MC	39.54	39.18	39.75	37.17	36.03	37.51	39.44	39.01	39.68
		28.20	28.60	28.50	26.84	26.43	27.11	28.45	28.13	28.45
4	PC	41.51	40.30	40.66	39.78	37.22	38.81	41.61	40.22	40.91
		29.31	28.17	29.25	28.25	26.72	28.12	29.06	27.78	29.10
	MC	40.82	40.42	40.46	38.86	37.33	37.80	39.80	38.11	38.35
		33.18	33.30	33.60	32.39	31.81	32.50	33.31	33.14	33.54
5	PC	45.13	45.46	45.42	43.53	42.05	43.26	45.86	45.45	45.41
		35.90	33.92	35.24	34.59	32.50	33.82	34.54	33.53	34.82
	MC	42.50	42.61	42.27	41.75	40.22	41.02	42.45	42.33	42.31
		36.58	36.43	37.30	35.22	35.11	35.44	36.35	36.16	36.78

Remark: PC refer to cars, MC refer to motorcycles, Normal number refers to off-peak time; Underlined number refers to peak time

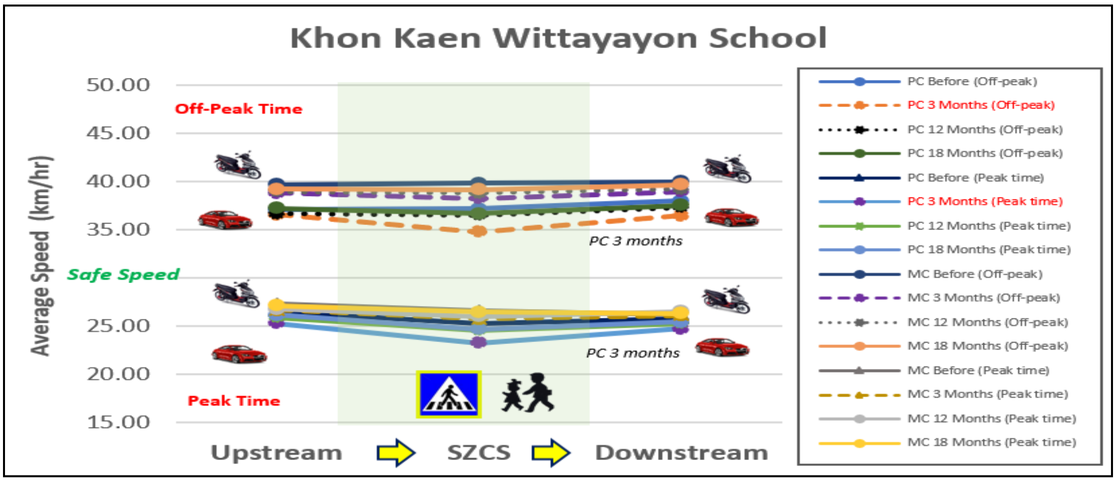

Figure 5: Examples of the comparison of average speeds before and during Project implementation

Table 5 depicts the change of speed in percentage at each implementation period. During the first 3 months, the average speed reduced at the point where different traffic attributes were installed. The average car speed reduced 6-11% during off-peak hours and 5-8% during peak hours. The average motorcycle speed reduced 4-8% during off-peak hours and 3-6% during peak hours. The average speed during the first 3 months of Project implementation of both cars and motorcycles reduced significantly. However, after 12 months of Project implementation, the average speed in each study site reduced slightly with no statistical significance. It was noted that vehicle users might be familiar with the different signs of SZCS Project, which affected the speed use behavior until the average became similar to the period before Project implementation.

Table 5: Percentage of speed changes during each implementation period

NO.	Types	Change of speed (%)								
		3 Months after			12 Months after			18 Months after		
		A	SZCS	C	A	SZCS	C	A	SZCS	C
1	PC	-4.11*	-10.83*	-5.70*	-2.25	-2.62	-2.06	0.02	-1.21	0.40
		-5.92*	-7.62*	-7.70*	-0.18	-0.93	-0.61	-1.47	-0.56	-0.72
	MC	-3.74*	-5.25*	-5.00*	0.38	0.12	2.57	-0.22	-0.35	-0.08
		-4.79*	-3.72*	-7.01*	-1.64	-0.83	-1.55	-1.10	-0.94	-0.38
2	PC	-1.34	-6.46*	-4.03*	-1.10	-1.75	-1.84	0.47	-1.37	-1.31
		-4.64*	-7.90*	-4.26*	-2.23	-2.46	-2.09	-1.43	-2.06	-1.36
	MC	-2.11	-4.00*	-2.54*	-1.78	-2.63	-1.91	-1.10	-1.70	-0.68
		-2.42*	-3.31*	-0.34*	-2.01	-2.37	1.11	-0.70	-0.56	0.31
3	PC	-6.55*	-10.88*	-6.23*	-1.04	-2.18	-0.97	-1.16	-1.68	-0.62
		-4.16*	-7.85*	-5.39*	-2.21	-2.35	-1.68	-1.60	-1.39	-0.78
	MC	-6.01*	-8.04*	-5.63*	-1.37	-1.91	-0.84	-0.26	-0.44	-0.18
		-4.82*	-7.59*	-4.88*	-2.02	-2.48	-1.30	0.89	-1.64	-0.18
4	PC	-4.17*	-7.64*	-4.54*	-1.19	-1.24	-1.73	-0.25	-0.20	0.62
		-3.62*	-5.15*	-3.86*	-1.54	-1.60	-1.64	-0.85	-1.38	-0.51
	MC	-4.80*	-7.64*	-6.57*	-2.37	-2.42	-2.41	-1.52	-0.76	-0.75
		-2.38*	-4.47*	-3.27*	-1.81	-2.01	-1.93	0.39	-0.48	-0.18
5	PC	-3.46*	-7.50*	-4.76*	-0.24	-0.68	-0.20	1.62	-0.02	-0.02
		-3.65	-5.00*	-4.03*	-2.01	-2.05	-1.45	-1.56	-1.15	-1.19
	MC	-1.77	-5.61*	-2.97*	-0.09	-1.32	-0.25	-0.12	-0.66	0.08
		-3.72*	-3.62*	-4.99*	-1.48	-1.67	-1.50	-0.63	-0.74	-1.39

Remark: * Significant at 5% level, Normal number refers to off-peak time and Underlined number refers to peak time

3.3 Evaluation of Road Safety of Pedestrians Based on iRAP Standard

The comparison of the average scores of pedestrians' road safety is shown in Table 6. The analysis was done during the period when vehicles used their highest speeds. The Star Ratings and scores of road safety were found to change after the application of Project measures, indicating the parameters of speed management / traffic calming. The safety Star Rating levels of the pedestrians increased from 3 stars to 4 stars at all study sites. However, the researchers noted that the different parameters set in the system had some constraints such as the parameter set for school zone warning. The parameters could affect the scores if at a school area, signs had been damaged and were at an unsuitable point, or the zebra line and colors had faded. The system was able to indicate only the school zone static signs or road marking. Moreover, the speed limits in urban areas or at Thai school areas could not be enforced; they are only signal information that is different from developed countries. Thus, the parameters could result in the scores unable to reflect the reality at each site.

Table 6: Scores and star ratings showing road safety of pedestrians based on iRAP standard

NO.	Schools	Pedestrians total scores*		iRAP Star rating	
		Before	SZCS	Before	SZCS
1.	Holy Redeemer Northeastern region School	18.28	5.27	★★★	★★★★
2.	Khon Kaen Wittayayon School	29.24	9.75	★★★	★★★★
3.	Kanlayanawat School	18.28	12.10	★★★	★★★★
4.	Kaennakhon Wittayalai School	30.78	8.07	★★★	★★★★
5.	Sotsuksa Khon Kaen School for the Deaf	34.54	12.92	★★★	★★★★

Remark: * Data were evaluated using ViDA – Online software (17)

Road Accident Statistics and Evaluation of Investment Worthiness

The comparison of road accident data one year before and one year during the implementation at SZCS Project with 13 schools situated on the 3 routes is shown in Figure 6. Road accidents of all cases were found to decrease 28%, slight injuries decreased 14%, severe injuries decreased 50%, and death rates decreased 67%. If only pedestrians were taken into account, the decrease was found from 4 cases to 2 cases (a 50% decrease). However, when SZCS Project began, the deaths were still recorded, especially among pedestrians. The data demonstrates the fragility of pedestrians. Even it is in urban areas or areas close to schools, if crashes involve bigger vehicles, severity of injuries can result that possibly lead to death.

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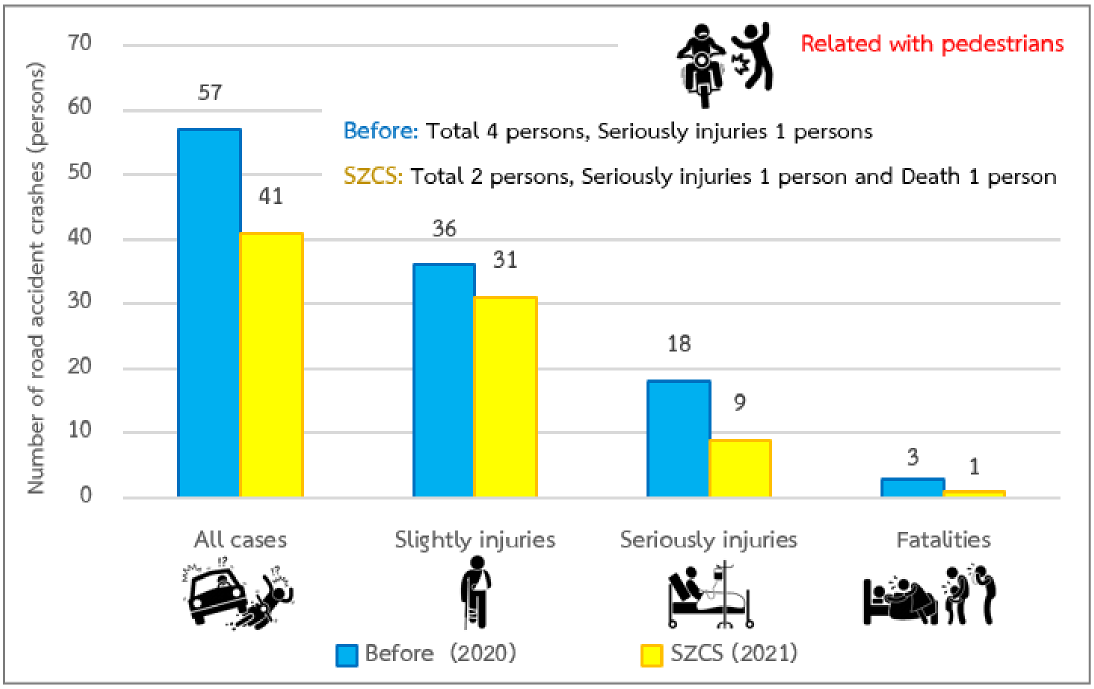

Figure 6: Comparison of road accident data

Table 7 depicts the results of the worthiness of investment. The data shows the decrease of death and injury cases during the one-year period of SZCS Project. In economics terms, such implementation is worth the investment (Benefit-Cost ratio > 1.00).

Table 7: Project evaluation by benefit-cost ratio

Evaluation	Average cost and worthiness
Before the Project (Accident cost)	614,213 Dollars
After the Project began (Accident cost)	277,322 Dollars
Construction budget (13 schools)	35,957 Dollars
Benefit-Cost ratio	9.36 > 1.00 (It is worthwhile.)

Remark: 1 dollar is worth 35.32 Thai Baht.

4. Conclusions and Discussion

To conclude, the research results indicate that SZCS Project is worth the investment. The empirical information derived from the research demonstrates that the Project can be transferred to different groups of road users for their safety, especially the fragile school pupil group with great risk of road accidents, due to their lack of experience and road using skills. The study and evaluation was divided into 4 aspects: 1) vehicle speeds, 2) degrees of road safety of pedestrians based on iRAP standard, 3) traffic accidents in the Project areas, and 4) worthiness of investment. The results show that: 1) The speeds decreased during the first 3 months of project implementation. The average speeds decreased both during peak and off-peak hours at the points where traffic signs and tools were installed (the Project sites) with statistical significance. However, after 12 months, the speeds reduced slightly with no statistical significance. 2) The Star Ratings of road safety among pedestrians increased from 3 to 4 stars, which is the consequence of the Traffic Calming of SZCS Project. Nevertheless, the parameters in the ViDA – Online software still have some limitations that could not reflect certain contexts of usage in Thailand. 3) There was a significant reduction of accidents and injuries, which agrees with the study by iRAP that one level of Star increase of a project will reduce death rates and severe injuries to 60% (16). 4) This project is worth the investment. However, the increasing average speeds 12 months after the Project began show that vehicle users might become familiar with the measures, and therefore resumed their speeds that are close to the period before the measures were taken. This finding agrees with other research studies (22,25,43), and confirmed the efficiency of Project implementation during a short period (1-3 months). The improvement method of this Project also indicates relatively low budget and appropriateness of prompt implementation by local organizations.

The results of this research can be applied in education, with importance placed on instruction and addition of necessary skills for school pupils, by means of addition of subject contents related to safety of daily life. The instruction can be in the form of simple communication such as cartoon or animation in order to reach the school children group. The content can be on the importance of walking across the zebra crossing, the meaning and importance of different traffic signs as well as the special signals added at the zebra crossing such as the Advance Stop Line, or Optical Speed Bars. The necessary skills can be developed through regular curriculum or by short training for road using. These can also be applied to the public in general. The content can be specified as the major criterion for authorizing driving license or extension of the license to all vehicle drivers. As such, all road users will perceive and become aware of the importance of road using at school areas.

In engineering terms, external organizations whose works deal with roads, should design and manage the road ambient in accordance with engineering principles so that greatest safety among all types of road users is achieved. The standards should be within 3 stars of iRAP, especially at school zones. For example, a traffic island should be built and signs with flashing lights installed at the traffic island, a fence between pedestrian walkways and road traffic installed, etc. Or else, the principle of traffic calming can be applied, for this builds perception as well as controls the risk behaviors of vehicle drivers. Traffic calming includes the category with direct impact on risk behaviors by modifying the physical characteristics of roads to reduce the speeds of all vehicle types, such as expanding walkways and decreasing road width, decreasing crossing length, building a middle island, elevating road surface level at the crossing. The other category of traffic calming is increase of vicinity before the crossing; use of optical speed bars, rumble strips, CCTVs or closed-circuit television cameras, vibrated traffic calming, sound warning systems, and pedestrian crossing flags. These attributes build perception and control risk behaviors, but they still require strict enforcement of traffic laws such as limiting speed at school zones to within 30 km./hr., based on WHO's recommendation. These, coupled with the above-mentioned measures, would bring utmost efficiency.

The limitation of this research and future research is the limited study sites specific to arterial roads. Qualitative research has not been conducted, such as on attitudes, beliefs and correlation of road crosser data and the measures that would lead to clearer research results.

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