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Minimum Standard of Traffic Safety Devices at Primary School Zone Black Spot in Phnom Penh

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Abstract: *Pedestrian safety, especially for schoolchildren, constitutes a world concern. For the condition of peak hour, we observed that there are many urgent problems of conflicting between traffic flow on the road and the pedestrian crossing but it varied through two underlying factors, road type which refer to traffic volume and pedestrian (students) volume crossing the road. Traffic conflict would be the best feature of measuring the potential of the traffic accident. This study presented situations and traffic safety devices at school zones especially in front of operating school gates. The objectives of this paper are: (1) to compare the student's conflicting accident to vehicle with the present of traffic safety devices (TSDs) in front of 35 primary school gates in Phnom Penh city and (2) to recommend a minimum standard of TSDs to prevent increasing accident for school children. For the TSDs refer to: Zebra Road crossing, School crossing warning, school zone warning, Speed limit, and slow down sign. Questionnaire was designed to interview School director or teachers to have the data of student such as the total number of students, number of students in each session, percentage of student who need to cross the road, transport mode and some recording information about accident on students in front of the 35 selected primary school gate in Phnom Penh. Some additional data we got from interviewing the traveller and vendors along the school zone about the situation of traffic accidents. It can be used to compare to the data we got from the school director or teachers. The existing geometry was observed and recorded such as (TSDs, Road Type, Lane width, Walkability, and overall behavior) for 35 target schools also. The locations of TSDs are measured from the school gate and the traffic volume was recorded in 45min at the peak hours. After getting numerical data from a survey of each sample school so that we can compare to the score obtained from evaluation on TSDs of each school, the effectiveness of TSDs on accidents will be shown. Regression of two-sample mean test models was used to analyse and show results through input variables. The effective factors of traffic accidents were identified such as Traffic volumes, number of students and speed etc. The minimum standard of TSDs in front of school gates was designed and proposed base on effective factors to conduct and enforce for protecting schoolchildren from high-risk situations of accidents. In conclusion, TSDs is very important for facilitating schoolchildren to cross the road and prevent the traffic accident, especially saving life of schoolchildren from accidents.*

Keywords: Traffic safety devices; School zone; Black spot; Traffic conflicting

1. INTRODUCTION

1.1 Background

Cambodia is a developing country in Southeast Asia, has a vibrant history when coming to transportation. The development of transportation in Cambodia can be traced back to ancient times, displaying the country's rich cultural heritage and interactions with neighboring civilizations. The emergence of the Khmer Empire, which reached the peak during the 9th to 15th centuries, led to the construction of remarkable infrastructure projects. A vast network of roads, bridges, and causeways facilitated trade, travel, and communication throughout the empire. During the French colonial period, which began in the late 19th century, we saw significant changes in transportation system. The French implemented modern infrastructure, including railways, roads, and ports, to facilitate trade and administration. However, the devastating impact of the Khmer Rouge regime in the 1970s greatly affected Cambodia's transportation infrastructure. The country went through

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a period of turmoil and unrest, causing severe damage to roads, bridges, and other transportation facilities. Also, many experts, professional people, and important documents were almost destroyed. It took years of reconstruction and restoration efforts to bring the transportation system back on track [1]. Since the reintroduction of a market-oriented economy in the 1990s until 2023, Cambodia's transportation system has witnessed notable advancements, which is the reason for Cambodia to have a good law, management and standard to control traffic and save Cambodian's lives from traffic accident.

1.2 Standard of TSD of Cambodia

For unstoppable development of transportation in Cambodia from the civil war, therefore it is the reason to have transportation management and standard as much as possible to prevent the impact from this development. By the lack of all these documents, causing Cambodian drivers have low education, unruly driving, which cause frequent traffic accidents. By considering that the task of the Ministry is to recompile standard, the center of technical research of public work was discussed with technical expert officer of General Department of Transportation, Ministry of Public Work and Transportation (MPWT) for first preparation Traffic Control Devices appendix in 1995 and to be launched on 22, August, 1995. The Standard of traffic control devices was updated and relaunched two time more in 2002 and 2011 for the last update till now. The standard of traffic control devices has 2 volumes: volume 1 for signs and its functions and the volume 2 for sign fabrication manual which is the standard that is still lacking of some many important points to develop [1].

1.3 Problem Statement

The "Make Roads Safe" report by the Commission for Global Road Safety (2011) confirmed traffic accidents as the primary cause of youth mortality worldwide. In addition, the Chair of the Commission for Global Road Safety emphasized that "one of the reasons the problem has not been addressed is the absence of accountability of road safety at the international and domestic levels [2]. The World Health Organization (WHO) stated that in 2018, more than 1.35 million people were died and 20-50 million were injured or disabled due to traffic accidents. Most of the victims were between 5-29 years old [3]. Children are considered one of the most vulnerable groups and 500 children in the world is killed every day by traffic accident. Traffic accident are serious social problems that have detrimental impact on human health as well as lead to high medical expenses, production loss, and property damage [4].

Particularly, the Four-Year Report 2006 - 2009 of the Cambodia National Road Safety Committee (Russian Federation, 2009) shows that the number of traffic fatalities in Cambodia has almost doubled in the last five years. In 2008, 1638 people were killed and 7200 severely injured. (Russian Federation, 2009) also shortly described the traffic safety situation in Cambodia that: Traffic characteristics: million registered vehicles, 20% annual growth 79% motorcycles, 13 % cars, 6% trucks and Fatalities: type of transport: 68% motorcycles, 13% pedestrians 4 % bicycles, 7% cars [5]. In addition, the annual report on traffic accidents released by the National police, the number of deaths was 1,497 in 2021 as compared to 1,646 in 2020, a decrease of 149 deaths or 9 percent. In contrast, the number of deaths increased to 1,709 with 4,026 of injuries in 2022. This can show that the traffic safety is still the main issue in Cambodia which stand in the serious situation to solve.

Pedestrian safety especially for school children constitutes a world concern. For the condition of peak hour, we observed that there are many emergent problems of conflicting between traffic flow on the road and the pedestrian crossing but it varies through two underlying factors, road type which refer to traffic volume and pedestrian (students) volume crossing the road [6].

Fig. 1. Congestion and vulnerable situation of school children crossing and walking on the roadway (Source: authors)

As shown in Fig. 1, the bad situation of congestion happened in front of Stoeung Meanchey and Toul Kauk primary school (investigated in June 2023). Even though the congestion was not too long, it caused many conflicts which resulted in the increase of traffic accidents. Moreover, the vulnerable situation of school children crossing the road without facilitation at the end of each session of the school and walking on the travel way while the sidewalk was blocked by

vendors or no sidewalk. Many cases of traffic accidents were result from uncontrolled speeding of drivers along the school gate for they did not notice that they were crossing the school zone because of a lack of traffic control devices and out standard traffic sign.

1.4 Objective

Traffic conflict would be the best feature of measuring the potential of the traffic accidents [7]. This study presents situation and traffic safety devices at school zones especially in front of operating school gates. The 2 objectives of this paper are: the first is to compare the student's conflicting accident to vehicle with the present of traffic safety devices (TSDs) in front of 35 public primary school gates in Phnom Penh city and the second is to recommend a minimum standard of TSDs to prevent increasing accidents for school children.

2. LITERATURE REVIEW

The Manual on Uniform Traffic Control Devices (MUTCD) is approved by the Federal Highway Administrator as the National Standard of U.S. until 2009 edition. MUTCD mentioned that the purpose of traffic control device, as well as the principles for their use, is to promote highway safety and efficiency by providing for the orderly movement of all road users on streets, highways, bikeways, and private roads open to public travel throughout the nation [8].

An engineering study of traffic conditions, pedestrian characteristics, and physical characteristics of the location shall be performed to determine whether installation of a traffic control signal is justified at a particular location. The investigation of the need for a traffic control signal shall include an analysis of factors related to the existing operation and safety at the study location and the potential to improve these conditions, and the applicable factors contained in the following traffic signal warrants:

Warrant 1, Eight-Hour Vehicular Volume
Warrant 2, Four-Hour Vehicular Volume
Warrant 3, Peak Hour
Warrant 4, Pedestrian Volume
Warrant 5, School Crossing
Warrant 6, Coordinated Signal System
Warrant 7, Crash Experience
Warrant 8, Roadway Network
Warrant 9, Intersection Near a Grade Crossing.

The satisfaction of a traffic signal warrant or warrants shall not in itself require the installation of a traffic control signal. In section 4C.06 Warrant 5, School Crossing: the school crossing signal warrant is intended for application where the fact that schoolchildren cross the major street is the principal reason to consider installing a traffic control signal. For the purposes of this warrant, the word "schoolchildren" includes elementary through high school students [8].

Traffic Engineering Practices for Small Cities (TEPSC) was made by Kansas Department of Transportation to assist local officials in the application of traffic engineering practices within the community of small cities in order to solve the traffic problems encountered by the local officials are not unique. The primary resource for this handbook is the MUTCD 2003. This handbook mentioned that School areas often require special traffic control treatment because of the danger to children, who are generally less likely to be able to judge traffic situations. The question facing traffic managers is how to best handle the school safety problem in light of the many issues and factors involved. Parents and school officials will often make demands based on emotions rather than a factual set of circumstances. City officials will be equally concerned with the safety of the children but will be required to work within budget constraints and the demands of the total driver population. What is needed is a program that is acceptable and utilized by educators, enforcement officials, parent-teacher groups, the children and others involved. The standard has shown the answer of many question related to school crossing which can be use in small city such as: the location of school crossing, the people to involved in developing a safe school crossing plan, how can one tell if a school crossing is unsafe, the alternatives for protecting school crossing, the justification of overpass and underpass of school crossing, the reduce speed and speed limit at school crossing, and some standard traffic control sign should be used for school [9].

The edition of the British Columbia Manual of Standard Traffic Signs & Pavement Markings (MSTSPM) replaced the interim edition dated May 1989 and was in effect October 1, 2000. The edition included the information sign chapter and the pavement marking Chapter. This manual is in general conformance with the Manual of Uniform Traffic Control Devices for Canada. It also conforms with Motor Vehicle Act Regulations, Division 23, which specifies the designs for number of the signs contained within this manual. Standardization of design and application aids recognition and understanding of signs and is important in obtaining motorist compliance and cooperation. Motorists have a right to expect that any given traffic sign will always have the same meaning and will require the same response, regardless of where the sign is encountered. Similar situations where signs are warranted should, therefore, be signed in a similar manner. Chapters 2 to 6 of MSTSPM provides standards for designing and using of traffic signs, but is not intended to override good engineering judgment; nor are the recommended standards intended to be a legal requirement. While the manual contains language such as "shall" there may be circumstances where strict compliance with such requirements is not reasonable and it will be necessary to deviate from the requirements. In chapter 5 is the

important part for school and pedestrian signs which mention many useful signs for school crossing with its meaning and usage which is partly show with typical school crossing layout [10].

(Shabadin et al, 2022)'s study focused on the utilization of the facilities provided at school, exposure measures, and demographic characteristics of the schools in Malaysia. The facilities that are being considered in this study are; a zebra crossing, pedestrian bridge, drop-off, and pick-up zone, and the presence of a traffic warden. A total of 57 schools in Selangor were assessed and the important variables were analyzed using the Negative Binomial Regression model to identify the significant attributes. Non-parametric analysis was used to compare the differences in characteristics of the schools. The findings of the study conclude that the road type and pedestrian volume are the underlying factors that would increase pedestrian-vehicle conflict in the school vicinity [6].

(Varma, 2021) discussed the findings of a case study of an interactive curriculum spanning nine modules, which aided grade IV students of a school in New Delhi to re-imagine and co-create a safer school street. The curriculum is part of the Crosswalk Program by HumanQind. The program is focused on and aligned with the frameworks of the United Nations Sustainable Development Goals on road safety, human rights, and human-centric urban development. The geometry for school street was re-designed and propose to local authorities, with whose inputs a final design document including a technical plan and estimated cost was created and submitted to the Delhi Government and the Delhi Public Works Department (PWD) for potential implementation [11].

The effects of traffic control devices were studied by a researcher in China [12]. (Zhao et al, 2016) conducted a driving simulator experiment to assess the effects of school zone signs and markings for two different types of schools. The efficiency of these traffic control devices was evaluated using four variables derived from the driving simulation, including average speed, relative speed difference, standard deviation of acceleration, and 85th percentile speed. Results showed that traffic control devices such as the Flashing Beacon and School Crossing Ahead Warning Assembly, the Reduce Speed and School Crossing Warning Assembly, and the School Crossing Ahead Pavement Markings were recommended for school zones adjacent to a major multilane roadway, which is characterized by a median strip, high traffic volume, high-speed traffic and the presence of pedestrian crossing signals. The School Crossing Ahead Pavement Markings were recommended for school zones on a minor two-lane roadway, which is characterized by low traffic volume, low speed, and no pedestrian crossing signals.

3. METHODOLOGY

3.1 Selected Schools and roads Characteristic

35 schools were chosen in only Phnom Penh city based on the number of students ranking from higher to lower of 164 schools with two different types of roads (local road, and national road) in the city center and suburb area. Only one school among 35 selected schools has the pedestrian crossing flyover on national road 4 while some schools are on national road 2, 5, and 6 which are the main roads for accessing city center to suburb areas with high traffic volume without pedestrian flyover. Some other schools are on the local busy roads in the city center with small mess sidewalks, blocked sidewalks or without sidewalks. Some school gates are located on local road but it is not too far connecting to the main road and student still need to cross the main road, so they were still classified for schools on that main road.

There are 2 typical school sessions. Schoolchildren attend school for the morning session at 7:00 am and ends at 11:00 am, while a second schoolchildren attends the afternoon session at 1:00 pm and continues until 5:00 pm. Many problems were found in front of the school zone at peak hours which happened at the end of all sessions (around 10:45 to 11:30 for morning sessions and 4:45pm to 5:30pm for afternoon sessions).

There are 2 types of roads that were classified as one-lane and two-lane roads in each direction. Most main roads have 2 lanes each direction with or without median but some sections of those roads have only one lane without lane divide marking lines from shoulders which cause messy traffic flow on lane and shoulder. The local roads have only one lane each direction which mostly has no shoulder or lane divide marking line and around 50% of one-lane roads has no sidewalk or sidewalk was blocked.

3.2 Data Collection for interviewing

Questionnaires was designed to interview School director or teachers for the necessary data of student such as the total number of students, number of students in each session, percentage of student who need to cross the road, transport modes and some recording information about accident on students in front of the 35 selected primary school gates in Phnom Penh. Some additional data we can get from interviewing the travelers and vendors along the school zones about the situation of traffic accidents. It can be used to compare to the data we got from school directors or teachers. Another necessary data could be the type of transport modes which cause the crash at school gates. The surveyor had a training session to make sure that they can collect the usable data following the questionnaire and target schools.

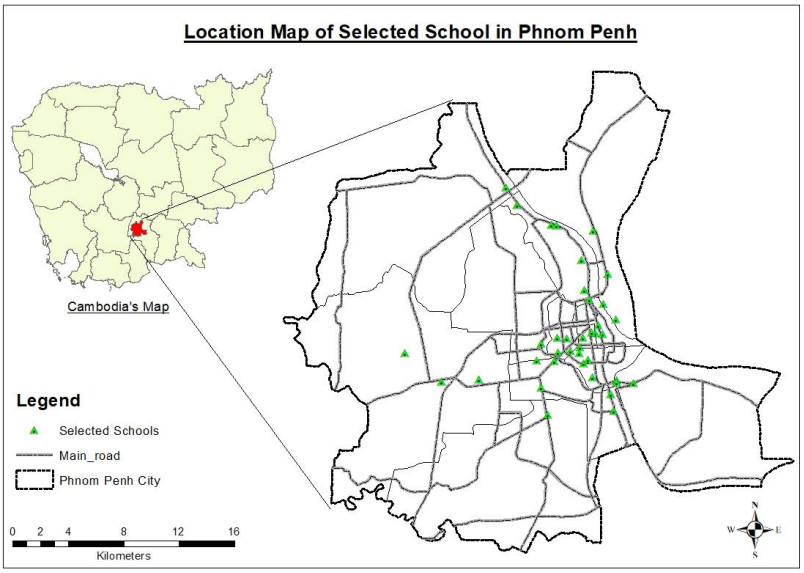


Fig. 2. Location Map of Selected Public Primary School in Phnom Penh city (Source: authors)

3.3 Data Collection for Measuring

The existing geometry is observed and recorded such as (location of TSDs, road type, road width, Walkability, and overall behavior) for 35 target schools. The TSDs refer to: zebra road crossing, school crossing warning, speed limit, school zone informing warning, slow down sign, and some other necessary signs. The locations of TSDs are measured from the school gate by using a roller distance measuring meter. The traffic volume is recorded in 45minutes at the peak hours which is the most conflicting duration of each ending session (10h45 to 11h30 for morning session and 16h45 to 17h30 for afternoon session) by using SONY camera HDR-CX405 for counting the vehicles. The vehicle types were grouped into 5 categories such as motorcycle (MC), tricycle/Bajaj, car/family car, bus and truck. Speed was recorded by speed gun (Bushnell velocity radar gun) for average and maximum travel speed during peak hours for each vehicle type too. All these data measurements were conducted around one month from early of June to mid of July 2023 parallel to the interview survey.

3.4 Two-samples mean comparison test

Two-sample mean-comparison test is one of regression test for hypothesis testing which is used to explain the behavior of a dichotomous dependent variable. The test has both population distribution are normal, so that $X_1, X_2, \ldots\ldots X_m$ is a random sample from a normal distribution and so is $Y_1, Y_2, \ldots\ldots, Y_n$ (with the X's and Y's independent of one another). The plausibility of these assumptions can be judged by constructing a normal probability plot of the x_i's and y_i's. [13].

(eq.01)

T is test value, $\bar{X}$ - $\bar{Y}$ is the observed difference, $\mu_1 - \mu_2$ is expected difference and the dividend is the standard error of the differences.

4. RESULTS AND DISCUSSION

4.1 Results by Interviewing

From the interview, selected schools were shown in the table with the number of students and the number of accidents per year for 2022-2023. Based on the number of road's lane in each direction in front of the operation school's gates as shown in Table 1, there are 22 schools with one lane and 13 schools with two lanes in each direction. The lane width ranges from 3m to 5.5m, shoulder width 2m to 6m and sidewalk width from 1m to 6m. 71% of sample schools have no shoulder only with37% have sidewalks. Another information about student's transport modes, is divided into 5 categories such as bike cycle, walk, school bus/Tuk Tuk, motorcycle and bring or pick-up by their parents. The data showed that there are 23 schools that have 50%-90% of going by parents, 5%-40% by bike cycle and walking, 0%-20% by bus and Tuk Tuk and 0%-10% by motorcycle. Other 12 schools have 10%-40% of going by parents, 10%-50% by bike cycle, 30%-70% by walking, 5-50% by school bus/ Tuk Tuk and 0%-10% by motorcycle.

Table 1. Selected School ‘s information (2022-2023)

ID	School's Name	# of Students	# of Accidents (all injuries)	Road Width (each direction)			
				# of Lane each direction	Shoulder Width (m)	Lane width (m)	Sidewalk Width (m)
01	Chamroeun Cheat	136	1	1	0	5	0
02	Chraing Chamres	2195	0	1	0	5	0
03	SAKURA Kbal Chroy	500	0	1	2.5	3.5	3
04	Chroy Changvar	1161	24	1	2.5	3.5	3
05	Phnom Daun Penh	695	0	1	0	4	4
06	Chaktomouk	1738	0	1	0	5	1
07	Wat Koh	193	2	1	0	4	2
08	Kolap 1	3708	0	1	0	3	0
09	Ponhea Krek	3802	0	1	0	4	0
10	Chbar Ampeuv 2	850	18	1	0	4	0
11	Chbar Ampeuv 1	2202	0	1	0	5	3.3
12	Boeung Chhouk Prachum Vong	1253	24	1	0	5	4
13	Chey Chumneas	654	1	1	0	3.5	2
14	Boeung Trabek Keut	1005	1	1	0	5.5	2.5
15	Teuk La-ak	1222	0	1	0	3.5	0
16	Boeung Salang	1875	2	1	0	4	0
17	Wat Moha Montrei	334	1	1	0	4.5	3
18	Tuol Sleng	267	0	1	0	4.5	2.5
19	Tuol Svay Prey	600	0	1	0	4.5	3.5
20	Trapaing Krasaing	2188	24	1	0	3.5	0
21	Kauk Banhchoan	3274	0	1	0	5	2
22	Mittapheap	376	0	1	0	3.5	0
23	Chamreun Rath	1022	10	2	0	3	0
24	Prek Pneuv	1433	0	2	0	4	1.5
25	Prek Leap	1102	19	2	2	3	3
26	Kean Khlaing	522	0	2	2	3	2.5
27	Chak Angre Leu	876	2	2	2.5	3.5	6
28	Chak Angre Phoum 2	2067	1	2	4.2	5.5	0
29	Wat Tuol Tumpoung	763	0	2	0	4.5	5.8
30	Dangkor	3502	3	2	2.5	3	2
31	Sampeuv Meas	238	0	2	0	4	4
32	Aknouwat Reach Theany	1778	3	2	2	3	6,0
33	Russey	2528	2	2	2.5	3	2
34	Stung Meanchey	2989	0	2	2.5	3	2
35	Chumpou Voan	3000	2	3	6	3	0

There are only 18 schools that facilitated for students crossing the road by teacher and local authority but 30% of those schools are not always did this for every day and every end of session. Only at the peak hours, that has facilitating for students crossing the road to their home while there is no facilitating when students come to school at each stating session. That's mean all students who come to school by their own transport modes (bike cycle, walking, motorcycle), they need to cross the road by their own. Parallelly, the traffic training course was done two times for 4 schools, 1 time for 12 schools and nothing for others per year 2022-2023 that we can assume that around 50% of sample schools that had traffic training course for students.

4.2 Results by Measuring

The existing TSDs was count and measured length from the middle of school's gates and the result shown (see **Table 2**) that there are 17 of school crossing warning signs with distant ranges from 3m- 190m, 1 of slow down sign with distant at 1m, 3 of 40km/h speed limit signs with range from 35m-290m, 13 zebra cross walk marking and 1 school zone warning with distant at 35m for 1-2 direction. For the opposite direction (2-1), there are 11 schools crossing waring with range of length from 15m-125m, 2 of slow down signs with 90m and 216m, 1 of 40km/h speed limit with 10m length, 5 zebra cross walk marking and 1 school zone warning sign with 316m from the school gate. It is to note that the 1-2 direction refers to the direction adjacent to the school gate while 2-1 direction is the opposite once. For the number of TSDs and their length from the school gates shown clearly on the lack of TSDs and some devices were installed without standard or engineering study for the school zone.

Table 2. Total Number of TSDs in front of 35 school's gates

Total number of Traffic Safety Device at School Zone (Direction 1-2)					Total number of Traffic Safety Devices at School Zone (Direction 2-1)				
									
17	1	3	13	1	11	2	1	5	1

The traffic volume was count in front of each sample school gates: there are 3 schools have traffic volume from 1063-1664 vehicles of in 45 minutes of both starting of session and ending of session (peak hours) and both directions while other 14 schools have 2711-4929 vehicles. For the remaining school have traffic volume range from 7056-13660 vehicles except Stung Meanchey primary school which the most congestion traffic in front of school gate with traffic volume of 25821 (see in

Fig. 3). Travel speed of vehicle for 16 schools is ranges from 50km/h - 60km/h and other 13 schools is ranges from 40km/h - 49km/h while only other 6 remaining schools is ranges from 30km/h - 39km/h. This is the image to show us that travel speed of vehicle in front of 82.85% of sample schools is over the speed limit in urban area of Cambodia (40km/h).

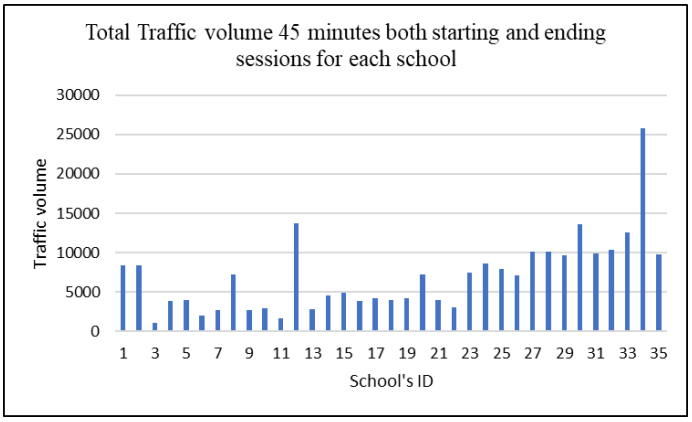


Fig. 3. Total Traffic Volume 45 minutes of peak hours for both directions

4.3 Estimation Result by two-sample mean comparison

Two-samples mean compare test was used to compare mean of two sample groups of school has (yes) and has no (no) traffic accidents to variable of total number of students (V1), number of students need to cross the road (V2), traffic volume (V3), maximum travel speed of vehicle (V4), number of TSDs (V5), Number of students who has own transport modes (V6), lane width (V7), and sidewalk width (V8) with the alpha level of 0.05.

Table 3. Two-sample t-test with equal variances of total number of students by Traffic accidents

Group	Obs	Mean	Std. Err.	Std. Dev.	[95% Conf. Interval)	
No	17	1516.29	303.20	1250.15	918.52	2204.06
Yes	18	1419.5	224.34	951.830	946.16	1892.83
Combined	35	1488.37	184.67	1092.53	1113.07	1863.67
diff.		141.794	374.23		-619.60	903.19
Diff= Mean(no)- mean (yes)						t= 0.378
H0: diff=0						degrees of freedom= 33
Ha: diff < 0			Ha: diff != 0			Ha: diff >0
Pr(T<t)= 0.6464			Pr (|T|>|t|) = 0.7072			Pr (T>t) = 0.3536

Base on the result from mean comparison test of total number of students (V1) between two groups of school with traffic accidents and without traffic accidents which is showed in **Table 3** Schools that have traffic accidents (Mean=1516.294, Std. Dev.= 1250.1565) compared to schools that have no traffic accident (Mean=1419.5, Std. Dev.=951.8309), t (33) = 0.37, p = .70 with the effective size (Cohen's d= 0.87), so the null hypothesis is that there is no significate difference that the null hypothesis is not rejected.

The same procedure was done for all independent variables which is shown in **Table** 4 to see the differences between two groups of schools that have and have no traffic accidents using independent t-test the alpha level of 0.05. The result showed that there is no significant difference for all variables Vi for all p-values are larger than 0.05 which all null hypotheses are not rejected. Anyway, from this result we can see that the mean of all variables of the school's group that has no accidents are significantly different from the mean of variables from another group except the variable number of students who own their transport mode that p-value closer to α=0.05.

Table 4. The comparison of independent variables of groups between schools has and has no traffic accidents, α=0.05

Variable	Have no Accident (No)			Have Accidents (Yes)						
	N	Mean	Std. Dev.	N	Mean	Std. Dev.	df	t	p	Cohen's d

V1	17	1516.29	1250.15	18	1419.50	951.83	33	0.37	0.70	0.87
V2	17	33.82	17.09	18	36.11	17.86	33	-0.38	0.70	-0.13
V3	17	6347.41	5755.23	18	7563.16	3755.77	33	-0.74	0.46	-0.25
V4	17	47.94	9.66	18	49.88	9.68	33	-0.59	0.55	-0.20
V5	17	1.64	2.02	18	1.33	1.45	33	0.52	0.60	0.17
V6	17	38.23	22.42	18	48.05	19.93	33	-1.37	0.17	-0.46
V7	17	5.14	1.74	18	5.52	1.97	33	-0.60	0.55	-0.20
V8	17	2.06	1.75	18	1.97	1.98	33	0.14	0.88	0.04

Table 5. The comparison of independent variables of groups between schools with higher traffic volume (>5000) and lower traffic volume (<5000), α=0.05

Variable	Higher Traffic volume (>5000)			Lower Traffic volume (<5000)						
	N	Mean	Std. Dev.	N	Mean	Std. Dev.	df	t	p	Cohen's d
U1	18	1740.38	1096.62	17	1221.52	1054.34	33	1.42	0.16	0.48
U2	18	37.22	17.42	17	32.64	17.33	33	0.77	0.44	0.26
U3	18	5.05	8.34	17	2.88	6.93	33	0.83	0.40	0.28
U4	18	52.83	9.15	17	44.82	8.43	33	2.68	0.01	0.90
U5	18	2.22	1.98	17	0.70	0.98	33	2.83	0.007	0.96
U6	18	41.66	18.23	17	45	24.87	33	-0.45	0.65	-0.15
U7	18	6.41	1.98	17	4.20	0.63	33	4.37	0.0001	1.48
U8	18	2.15	2.21	17	1.87	1.41	33	0.45	0.65	0.15

Two-samples mean compare test was also used to compare mean of two sample groups of school has higher traffic volume (>5000) and has lower traffic volume (<5000) to variable of total number of students (U1), number of students need to cross the road (U2), traffic accidents (U3), Maximum travel speed of vehicle (U4), number of TSDs (U5), Number of students who has own transport modes (U6), lane width (U7), and sidewalk width (U8) with the alpha level of 0.05 as shown in Table 5. For the comparison of these two groups of traffic volume, there are 3 independent variables (U4, U5 and U7) that are significant differences with the order of p-value (0.01, 0.007 and 0.001) smaller than the alpha level of 0.05 while other variables are no significant differences.

5. CONCLUSIONS

Based on the result above, we can see that there is no variable effect to the number of traffic accidents in front of sample school gates because of the confidence and the reliability of accident data which was not found from the field (some schools). Another reason is because of the facilitation for students from teachers and local authorities which is the main factor to reduce the conflict between traffic flow and school students crossing. This reduction of conflict is the best method that reduces the very high potential to lower rate of causing accidents [7]. Parallelly, in this study found that among 18 higher traffic volume schools with very high number of students, there are 13 schools which were facilitated for student

crossing and that reduced the mean of accidents of higher traffic schools (5.05) to be not so much higher (not significant different) from the mean of accidents of the lower traffic schools (2.88). So, the traffic volumes and number of students crossing the road are still the most effective factors in causing traffic accidents in the school zone. Speeding is still one of the major causes of frequent and severe traffic accident at school zones [14, 15] even though we found almost the same mean of speed between groups of school has and has no traffic accidents but it is still significant difference between groups of school with higher and lower traffic volume. Based on field investigation, it is also because of the differences of percentage of vehicle's travel speed (more than 50% of vehicles in school's group have traffic accident travel in maximum speed while only around 30% of vehicles in the school's group have no traffic accident travel in maximum speed). It means that the maximum speed was not a significant difference but it is much different for the number of vehicles travelling at that maximum speed.

Finally, we can conclude that the main factors that cause the traffic accidents at school zones are traffic volume and number of students crossing the road which effect conflict at school zones. Speeding is also the major factor effect on traffic accidents which was found in previous studies and in this study. Other factors are the number of TSDs and lane width of the road which are the difference between the school's group of higher and lower traffic accidents.

6. RECOMMENDATION

6.1 General Layout of Minimum TSD for School zone

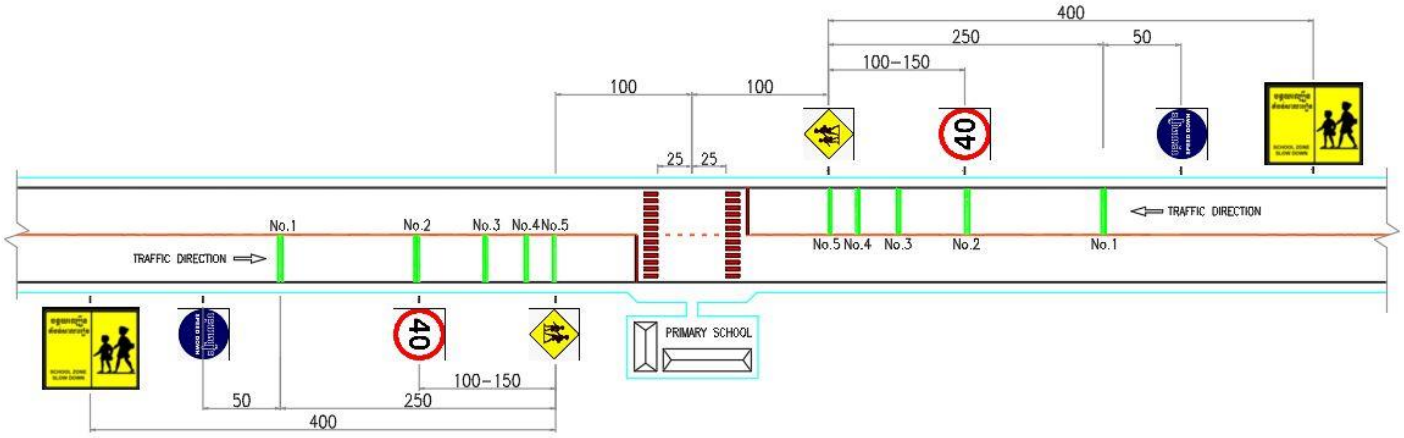
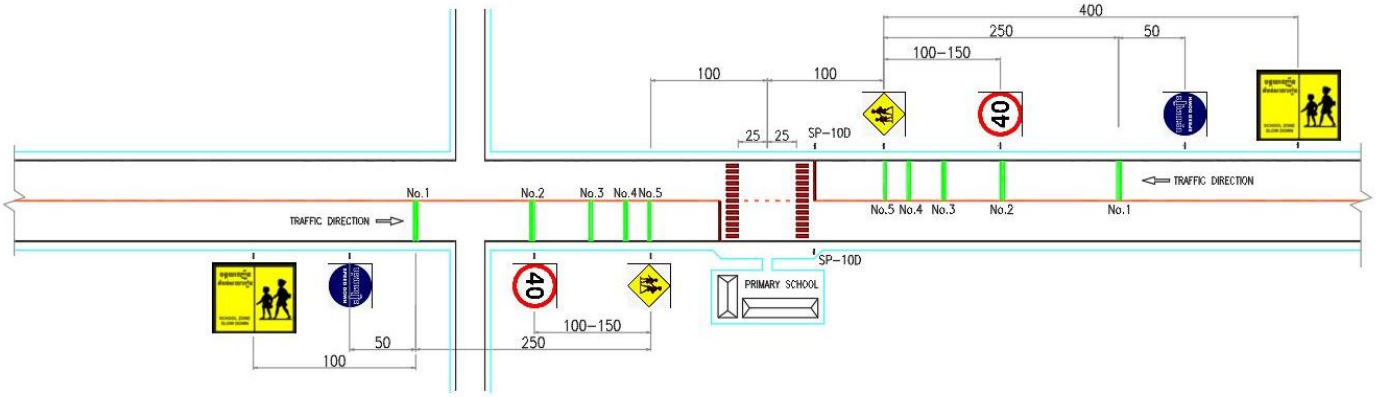
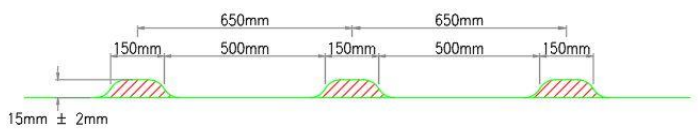


Fig. 4. General minimum standard of TSDs for School zone





RUMBLE STRIP DETAIL
Scale: NONE

Fig. 5. Minimum TSDs Layout for 4 legs intersection School zone with rumble strip detail

The minimum standard layout was prepared (see in **Fig. 4** and **Fig. 5**) to reduce the factor effecting traffic accidents that was found in result. It is to note that all dimensions are in meters unless otherwise indicated. The number of the rumble strips (bars) is 6 for No.1 and No.2, 5 for No.3 and No.4 and 4 for No.5 and the rumble strips extend from centerline to lane line marking of each direction only. Each strip surface should be painted with yellow thermoplastic marking. The general layout is used for school zones in the city with speed limit 40km/h. Traffic signs such as school crossing ahead warning, speed limit sign, reduce speed sign, slow down waring sign for school zone, and pedestrian cross walk marking were used and installed base on location each direction. In here, the pedestrian cross walk marking is marked 25 meters and school crossing ahead warning sign is installed 100 meters from the middle of school gate. For 40km/h speed limit sign is installed 100 to 150 meters more continually and others signs are installed accordingly as shown in the layout plan. The special cash is made for any school zones which is near the 4 legs intersection (not longer than 500m from intersection) with high total number of students (>1000) and high traffic volume (>5000) by adding the push to walk bottom attached with the push to walk signs SP-10D. The usage of this new proposed push to walk bottom and sign follows the standard of MSTSPM of Columbia. Also, this layout will not be intended to override the good engineering judgment and the intersection junction in 4 legs layout was not designed for that is needed to follow standard TSDs of MPWT of Cambodia. Sign ‘s shape dimension in the table were followed standard of traffic control devices of MPWT, 2011 of Cambodia, except pushbutton which follow to standard traffic control devices of Columbia.

Table 6: Information Table of Traffic signs

Signs						
Code	PW03-W1-33	PW03-R2-24	PW-03-R1-41	M4-04	W1-33	SP-10D
Reference	[1]	[1]	[16]	[1]	[1]	[10]

6.2 Additional Recommendation

Facilitating must be done by teachers or local authority to ensure that the road crossing is safe because this activity is so much effect to the conflicting of traffic flow and school crossing. Some important moveable safety devices need to be used to facilitate school children crossing the road such as moveable and portable stop signs. The enforcement of over speeding at school zones needs to be done to reduce the number of over speeding travel at school zones.

Training courses need to be done every school at least 2 times per year for each level of students because students need to be highly judgmental for crossing the road when they are no being facilitated by other people. The knowledge on traffic safety and law needs to be shear and promote to general social and the social media

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