Safety Moment-

Behavioral Observation of Pedestrian for Crossroad Design

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Abstract: In 2008, Taipei city fully renewed the traffic timing countdown system. However, a frequent phenomenon is that some people still try to cross the road in the last seconds of the green light or just run through the red light. This is one of the main causes of pedestrian accidents. On another note, types of pedestrian crossing vary in different parts of the city. It is thus important to study the types of pedestrian crossing and the different scenarios of pedestrian crossing the roads to identify factors that affect pedestrian safety. This study explores the Taipei city as a case study. A preliminary study including non-participatory observation is carried out to identify the five different types of pedestrian crossing and different behavioral patterns of pedestrians. Through this study, we confirm that (1) Hidden seconds will let people form a habit to ignore the pedestrian signals. (2) When the circulation is too long, pedestrians will try to cross the roads in the dangerous times, (3) Small crosswalks and crosswalks with traffic islands will both cause pedestrians to cross the roads in the hidden seconds, and (4) X-shaped crosswalks seems to be a good way to solve the problems in large roads.

Key words: Pedestrian crossing, Pedestrian behavior, Non-participatory observation, Pedestrian safety

1. Introduction

Traditional exclusive pedestrian signals show two lights: “red standing man” on the upper level and “green walking man” below the red man. When the "green walking man" is flashing, it shows a warning to pedestrians that there is little time remaining to cross the street. If a pedestrian is already crossing, they should quickly get to the other side or central traffic island. If they haven't yet started crossing, they are forbidden to cross [1]. Because of the lack of information for pedestrians to know when to cross the road, countdown displayers were added onto all of the exclusive pedestrian signals in Taipei City by 2008. By showing the numbers and dynamic patterns of the lights, pedestrians can have more reliable data for them to make their decision and thus the safety of pedestrians crossing the roads can be raised.

Besides, according to the analytical survey on pedestrian A1 accidents (fatal accidents) in the last three years by Department of Transportation, there are three reasons resulting in these accidents: pedestrians do not walk on crosswalk; pedestrians do not follow traffic signs or signals, and vehicles do not give ways to pedestrians. Each reason accounts for one-third. If pedestrians encounter red lights when crossing the roads, they have to stop and wait for the light. However, traffic behavior is not the main purpose of traveling. The time of waiting will raise the cost of traveling. Thus, pedestrians usually try to reduce the waiting time in order to travel more efficiently [2]. As

a result, we often found that when the light turns into red, there are still many pedestrians standing on the road or trying to across the street. This also indicates that why accidents often happen on crosswalks.

Chang and Lin pointed out that traffic signs or rules cannot fully satisfy every situation or all kinds of roads [3]. Thus, vehicles and pedestrians are required to know more about traffic rules and respect each other. In the present situation in Taiwan, drivers and pedestrians do not show enough respect to traffic signs. They often run through the red light or the yellow light just want to be fast and convenient.

The value of the setting of traffic signals is to provide more useful message to pedestrians and help them to cross the roads in a safe and fast way. However, by merely counting down seconds on the pedestrian signals, can pedestrians effectively estimate how much time they need to cross the roads? Take Taipei City as an example, there are too many kinds of pedestrian crossing. Whether present traffic lights and the countdown devices are suitable for different kinds of crosswalk remains doubtful. Therefore, this study aims to investigate the relationship between countdown displayers, pedestrians and the crosswalks. By analyzing and assessing the present design of the traffic signals, suggestions for designing related facilities will be made.

According to the Traffic Division of Taipei City Police Department, statistics shows that pedestrians account for 1 in every 8 deaths due to traffic accidents. 40% of traffic accidents happened on crossroads, which means the accidents happened just when pedestrians were crossing the roads [4]. The statistics also shows that violations to the traffic law made by pedestrians account for fourteen percent. Besides, according to the analytical survey on pedestrian A1 accidents (fatal accidents) in the last three years by Department of Transportation, there are three reasons resulting in these accidents: pedestrians do not walk on crosswalk; pedestrians do not follow traffic signs or signals, and vehicles do not give ways to pedestrians. Each reason accounts for one-third.

Since 2009, when the Summer Deaflympics held in Taipei City, the government has been promoting “Friendly Taipei, Pedestrians First.” Though this series of promotion did have some effect, the attitude of drivers’ giving ways to pedestrians is not completely carried out. National Police Agency of Ministry of the Interior announced that drivers’ not giving ways to pedestrians will be banned nationwide. According to the Regulations of Road Transportation and Management Penalty for the Violations, pedestrians have the right of way on crosswalks. If the drivers don’t give ways to pedestrians, they will be fined from 1,200 to 3,600 NT dollars. If pedestrians run through red lights, cross double yellow lines or traffic divider, they will be fined 300 NT dollars [5].

According to Article 203 in Convention on Road Signs and Signals [6], exclusive pedestrian signals should be equipped with two lights in a vertical way: “red standing man” on the upper level and “green walking man” below the red man. Article 207 mentioned: (1) When the "green walking man" is lit continuously, it shows that pedestrians could cross the street. (2) When the "green walking man" is flashing, it shows a warning to pedestrians that there is little time remaining to cross the street. If a pedestrian is already crossing, they should quickly get to the other side or central traffic island. If they haven't yet started crossing, they are forbidden to cross. (3) When the "red standing man" is continuously lit, pedestrians are forbidden from crossing the street. (4) When the "red standing man" is flashing, it shows that the crossing is working with another connected traffic control signal. Before crossing, pedestrians should stop, look left and right for oncoming vehicles and then carefully cross.

1.1 Convention on Pedestrian Signals with Countdown Devices

(1) According to Article 231 in Convention on Road Signs and Signals [6], the formula of red light flashing seconds is as follows:

Table 1. The length of red light

How to calculate	(P+L)/2V~(P+L)/V
(1)Unit: second (2)W：the width of the road. Unit: meter. (3)L：the average length (6 meters) (4)V：the average driving speed (the speed limit) Unit: m/sec	

(2) According to Article 231 in Convention on Road Signs and Signals [6], before the "green walking man" light ends, it should be flashing for a certain length of time. Here is the formula:

Table 2. The formula of red light flashing seconds

Flashing time	t = dw/v
t: flashing time dw: If there is no traffic island on the intersection, it should be the width of the roads; if there is a traffic island, it should be the width of the wider road. v: the walking speed (usually: 1 m/sec, near the school area 0.8 m/sec, near audible pedestrian signal: 0.5 m/sec)	

(3) According to Article 233 in Convention on Road Signs and Signals [6], the circulation for controlling traffic signals should be 30 seconds to 200 seconds.

From the formula of red light flashing seconds, we could know that the red light will be lit for longer seconds on wider intersections. Thus, wider intersections will result in larger circulation, which allows pedestrians enough time to cross the street. Before the green light of pedestrian signals ends, it will flash to warn the pedestrians that there is little time left. The seconds of flashing is calculated based on the width of roads and the speed of pedestrians. As a result, wider intersections will provide longer flashing time for pedestrians to react and thus protect their safety when walking on the roads. The setting of countdown devices on traffic lights and pedestrian signals can help pedestrians to control the time if they are crossing the roads in a safer way.

According to the report made by Institute of Transportation of Ministry of Transportation and Communications, countdown devices on traffic lights can reduce the problems resulted from the impatience of waiting or misidentifying the traffic light as malfunction [7]. However, the countdown devices can also create the danger of making drivers feel like on a car racing field. For countdown devices on pedestrian signals, they can not only practically help pedestrians to estimate the time they need to cross the roads but also reduce the chance of running a red light or delaying. On the other hand, the devices could also allow drivers to go through the intersection in the last seconds.

According to the analytical survey on pedestrian A1 accidents (fatal accidents) in the last three years by Department of Transportation, there are three reasons resulting in these accidents: pedestrians do not walk on crosswalk; pedestrians do not follow traffic signs or signals, and vehicles do not give ways to pedestrians. Each reason accounts for one-third. From this, we could conclude that pedestrians who try to cross the roads in the last seconds are one of the reasons that causing accidents. Countdown devices can help pedestrians to decide whether to cross the roads or not, and whether they decided to cross the roads is closely related to the time remaining for the green light.

1.2 Determinant factors for pedestrians to decide whether to cross the roads

Hatoyama and Shimomura stated that when pedestrians couldn't estimate the distance for crossing the roads or the time remaining for the green light, they will feel anxious. When there is enough information of the time and the distance, there won't be any significant changes on the walking speed of pedestrians. According to this research data in Japan, determinant factors for pedestrians to decide whether to cross the roads are: the distance of the intersection, the walking speed of themselves, and the time remaining for the green light [8]. We could know that pedestrian signals with countdown devices can provide more information for pedestrians. They are important data for pedestrians to judge whether they are able to cross the roads or not. Pedestrians will judge if they need to adjust their speed to cross the roads safely based on the distance. From this research in Japan, we could conclude that if there is enough information of the time and the distance, pedestrians can cross the road in a safer and more relaxed way.

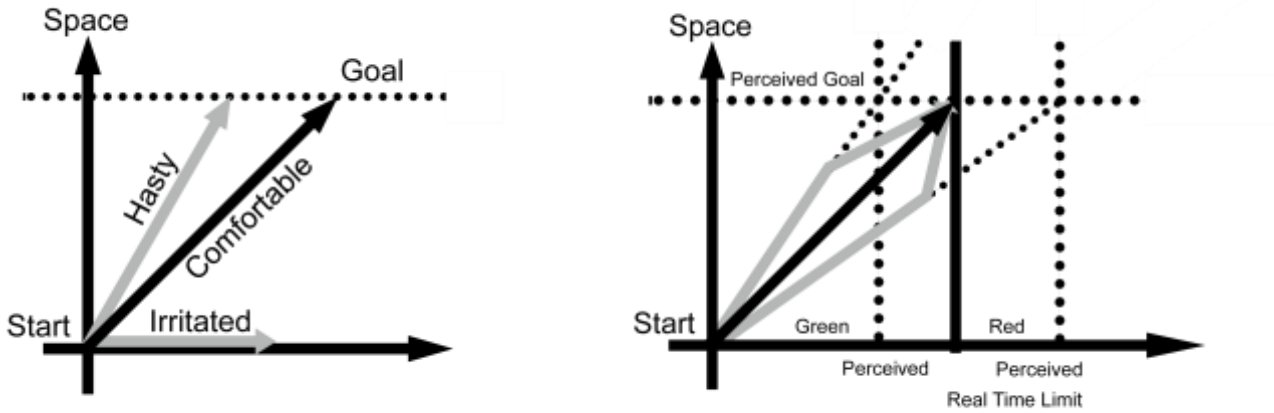

Figure.1 Behavior Design for Crosswalk Crossing

Besides, Hatoyama and Shimomura also found that when pedestrians wait the red light to turn green for too long, they will become irritated easily. When the green light is flashing, pedestrians will act more hastily when walking [8]. Thus, the design of circulation of the traffic lights is very important. We also found the length of the circulation will often affect pedestrians' behavior when they cross the roads. Especially in more complicated intersections, long time for the circulation will result in pedestrians try to cross the street in the last seconds of the green light. This will also bring about a hazardous situation that the light has already turned into red but the pedestrians are still on the crosswalks. We found that long time for the circulation probably is the main reason for accidents that happen because pedestrians do not follow the traffic lights and cross the roads as they wishes. There are many facilities that can protect pedestrians in the street design in England and Nederland. Traffic islands allow pedestrians can wait on them if the light becomes red when they are crossing the roads.

Keegan et al. used interview survey and observation to investigate the behavior of pedestrians when they cross the roads with or without countdown devices. The results show that if the pedestrian signals are equipped with countdown devices, people will tend to wait for the lights to turn green. On the other hand, if the circulation is shortened, there will be more chances for pedestrians to choose to stay. From the interview, most people reported that they are not willing to wait for the traffic lights because they think they can cross the roads safely. Those people who choose to wait think running through the red lights is dangerous. However, the time that pedestrians need to cross the roads and their attitude will change based on how many people walk together [9]. According to Tarawneh, he observed that different numbers of people (one person, two people, three people or above) who walk together spend different amount of time crossing the roads. It takes the longest time to cross the roads when there are three or more people walking together [10]. Thus, we could know that the numbers of people waking together affects the speed of pedestrians. If the pedestrians do not focus enough when they are walking or they stay on the crosswalk too long, this will lead to dangerous situations.

Mohammed M. Hamed analyzed how pedestrians decide to cross the roads or stay and wait from the various characteristics of road users and other considerations. The results shows factors influencing people's decision including gender, age, the number of children, frequency of crossing the roads, the number of the group, whether having a car, the distance from the destination, and experience of past traffic accidents. Pedestrians will evaluate themselves to see if it is safe enough to cross the roads based on their backgrounds [11]. Tung conducted a research on behavior of pedestrians of different ages. She mentioned that drivers and pedestrians who are going to cross the roads judge by distance. The faster the car is, the dangerous the situation will be. When it is evening, driver's choice time will be shortened [12]. Guerrier et al. used video clips to observe how pedestrians cross the roads. The results show that the average walking speed of people aged 20 to 40 is 1.3472 m/sec. The average speed of people aged over 65 is 0.9723 m/sec. The elderly tends to walk slowly than young pedestrians [13]. Thus, there are more risks for the elderly when they are crossing the roads. Pedestrian signals should be a universal design. It should be designed to fit the variety of groups and environments. When assigning the circulation time of signals, types of community should be taken into consideration in order to appeal to local community, which could make the best use of signals.

Accidents happened when pedestrians are crossing the streets are often heard. The research report points out the reason "pedestrians do not follow traffic signs or signals" accounts for one third of the total accidents. Thus, the signals should be designed to fit the variety of groups and environments in the society. Take Taipei City as an example, there are too many kinds of pedestrian crossing. The question whether present traffic lights and the countdown devices are suitable for different kinds of crosswalk remains doubtful. Besides, by merely setting countdown devices on green lights, could pedestrians of different ages estimate how much time they need to safely pass the crosswalk? Therefore, this study aims to investigate the relationship between countdown displayers, pedestrians and the crosswalks. By analyzing and assessing the present design of the traffic signals, suggestions for designing related facilities will be made.

2. Method

2.1 Using Non-participant observation

Non-participant observation is used in this study. Five common types of crosswalks in Taipei City were recorded for ten circulations to see the characteristics and behavior of pedestrians who tried to cross the road in the last seconds of the green light and those who still chose to enter the crosswalk even the light turned red. Also, the time that they need for their crossing was also recorded. This study will discuss different behavior of pedestrians on different types of crosswalks from the observed data.

*Non participant observation: researchers place themselves out of the observed scene, understanding the phenomena or behavior as observers or outsiders.

Table 3. Five common types of crosswalks in Taipei City

Type	Location	Distance	Hidden Seconds	The length of the green light / Circulation time
A Large crosswalk		17.6M	14 (s)	62/150 (s)
		Zhongxiao East Rd.and Xinsheng South Rd.		
B Small crosswalk		5.2M	36 (s)	60/150 (s)
		Jinan Rd. and Xinsheng South Rd.		
C Crosswalk with single traffic island		(4.4M-<7.2M>-4.4)/16M	12 (s)	60/150 (s)
		Jinshan South Rd. and Zhongxiao East Rd.		
D Large crosswalk with two traffic islands		(6.4M-<9M> -8M-<9M>6.4M)/38.8M	45 (s)	60/200 (s)
		Dunhua South Rd. and Zhongxiao East Rd.		
E X-shaped large crosswalk		22.4M	3 (s)	45/200 (s)
		Songshou Rd. and Shifu Rd		

*Hidden seconds: For the pedestrians' safety, there will be a certain amount of time that is reserved between the end of the red light of the pedestrian signals and the beginning of the green light of the traffic light. The reserved time is called "hidden seconds" in this study.

2.2 Record

Each sample was coded based on his or her basic information and the time he or she spent on crossing the road. The information of each pedestrian will include: gender (M/F), age, the number of companions (P). The time spent on crossing the road will be divided into two parts: the timing of entering the crosswalk and the timing of leaving

the crosswalk. There are four items: enter when there is (IG) seconds left for the green light, enter after the red light is lit for (IR) seconds, leave when there is (LG) seconds left for the green light, leave after the red light is lit for (LR) seconds. After this, the date will be followed by the total length of time he or she spent on crossing the roads (A). The behavior will be recorded in the following situations: whether staying on the traffic island (RI), running (r), stop (s), walking (w), whether going to cross another crosswalk (N), cross the road safely (S) or unsafely (US).

***Pedestrians' basic information**

For example: crosswalk type A, a 22-year-old female, entered when there is three seconds left for the green light, left after the red light is lit for 14 seconds, total time spent is 17 seconds, running, going to cross another crosswalk. The code for this sample will be: A-F-22-IG3-LR14-A17-r-N-US.

3. Results

3-1.Wider crosswalks, longer time spent on the crosswalks.

Each type of crosswalk was recorded for ten circulations. The average time for the last person who entered before the end of the green light and finished walking through the crosswalk is recorded.

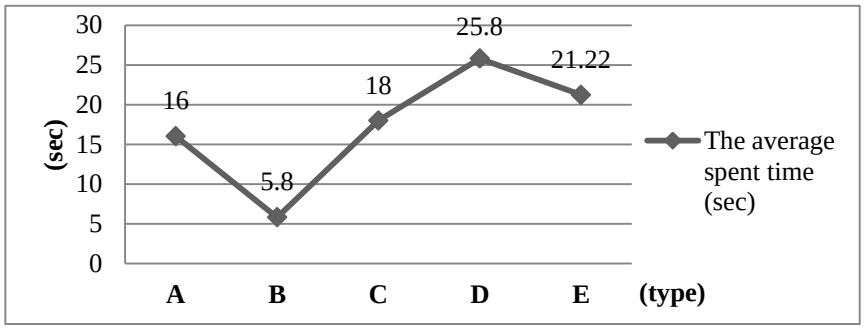

Figure.2 The average time for the last person who entered before the end of the green light spent on the crosswalk

According to figure 2, wider crosswalks, longer time spent on the crosswalks.

3-2.The distribution of male and female pedestrians who entered the crosswalk after the red light is lit

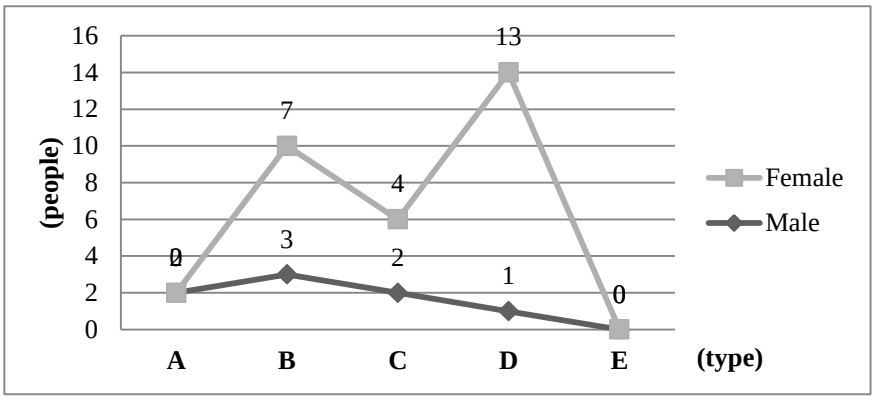

Figure.3 The distribution of male and female pedestrians who entered the crosswalk after the red light is lit

According to the Figure.3 statistic data, female pedestrians who chose to enter the crosswalk after the red light is lit are far more than males. Because of type A and type E are wider, there are less people choosing to enter the crosswalk. As for type B, because the crosswalk is narrower and there are more hidden seconds, females might think they can successfully cross the roads. Due to the setting of traffic islands in type C and type D, female pedestrians will also consider entering the crosswalk after the red light is safe.

Behavior coding (for ten traffic light circulations)

Table 4. Behavior coding for the last pedestrian entered the crosswalk before the end of green light

Type of crosswalk	staying on the traffic island (RI)	Running (r)	Stop (s)	Walking (w)	cross another crosswalk (N)	Safe (S)	Unsafe (US)
Type A	----------	7	1	6	2	5	5
Type B	----------	0	0	10	0	6	4
Type C	1	0	0	10	1	3	7
Type D	5	4	4	14	1	0	10
Type E	----------	4	0	9	0	6	4
Total	6	15	5	49	4	30	30

According to the Table 4.data, the average proportion for the last pedestrian entered the crosswalk and safely crossed the roads is 50%. However, the proportion for type C and type D is relatively lower (33% and 0%) since there are traffic islands in these two types of crosswalks. This shows that the setting of traffic islands will cause pedestrians to enter the crosswalk after the red light.

Table 5. Behavior coding for the pedestrian entered the crosswalk after the red light

Type of crosswalk	staying on the traffic island (RI)	Running (r)	Stop (s)	Walking (w)	cross another crosswalk (N)	Safe (S)	Unsafe (US)
Type A	----------	1	0	1	0	0	2
Type B	----------	0	0	5	0	0	10
Type C	1	0	0	6	1	0	6
Type D	5	3	6	18	3	0	14
Type E*	----------	*1	*0	*1	*0	*0	*2(horizontal)
Total	6	4	6	30	4	0	32

According to the Table 5 data, there are more pedestrians entered the crosswalk after the red light in type B and type C. However, in type A and type E, there is nearly no pedestrians entered the crosswalk after the red light. Besides, there is no person crossing the crosswalk after the red light. But in the on-site observation, some people will cross the street that is the same direction with the traffic flow. They crossed the horizontal crosswalk, which will put them into dangerous situation.

Combine table 4 and 5, we could find that in type B, C and D, pedestrians tend to walk through the crosswalk. This shows crosswalks with shorter distance or traffic islands, pedestrians won't get irritated easily and will walk

through the crosswalk. On the other hand, type A, D and E have more diverse behavior. Pedestrians will often run. According to the on-site observation, on large crosswalks, pedestrians will adjust their speed and pace based on how much time left for the green light and the distance to the destination. Thus, we could conclude that pedestrians have more diverse behavior on wider crosswalks.

4. Discussion

4.1 The relationship between types of crosswalks and the number of pedestrians who enter the crosswalk after the red light

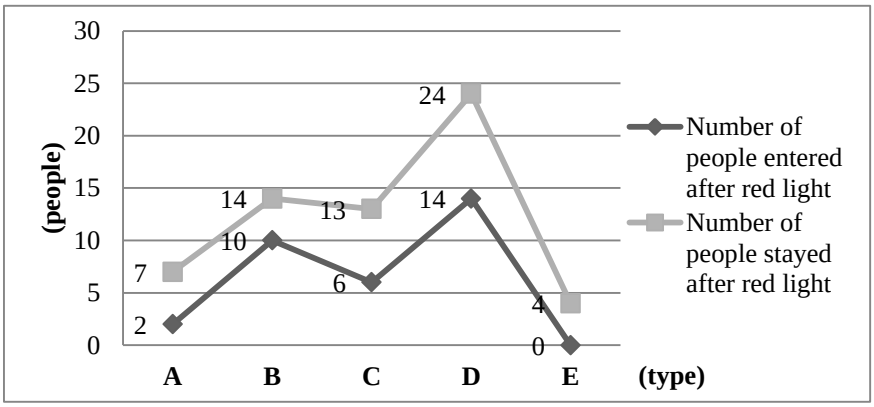

Figure.4 The relationship between types of crosswalks and unsafe pedestrians

According to figure 3 and the data, we could find that because type A and type E are large intersections where the traffic flow is heavy, the distance is long, pedestrians will spend more time on crossing, and there is no traffic island, there are less pedestrians trying to cross the crosswalk after the red light or stay on the crosswalk after the red light is lit.

Type D, also a wide crosswalk, provides traffic islands for people to stay. And this will cause pedestrians to enter the crosswalk in the last seconds of the green light or after the red light. We observed that even when there were some dangerous situations, people can stay on traffic islands for their safety. Traffic island is also found in type C, so there are also some people choose to stay on the crosswalk. Possible reason for this is the setting of traffic island, which will cause pedestrians to enter the crosswalk in the last seconds of the green light or after the red light.

Besides, the circulation time for type D is quite long and the distance is also long. If a pedestrian miss this green light, he or she has to wait for 140 seconds for the next one. The hidden seconds for type D are 45 seconds. This is comparatively longer than others and will cause people to run through a red light. As for type B, the hidden seconds are 36 seconds. The hidden seconds are quite a lot since type B is a relatively small intersection. Based on the hidden seconds and the distance, pedestrians will think they can successfully cross the roads. Thus, there are also some people enter the crosswalk of type B in the last seconds of the green light or after the red light. And this will result in people staying on the crosswalk after the red light.

4.2 Each type of crosswalks was recorded for ten circulations. This is the relationship between the number of people who entered the crosswalk before the end of green light and crossed the roads safely and the number of those who crossed the roads unsafely. (S v.s. US)

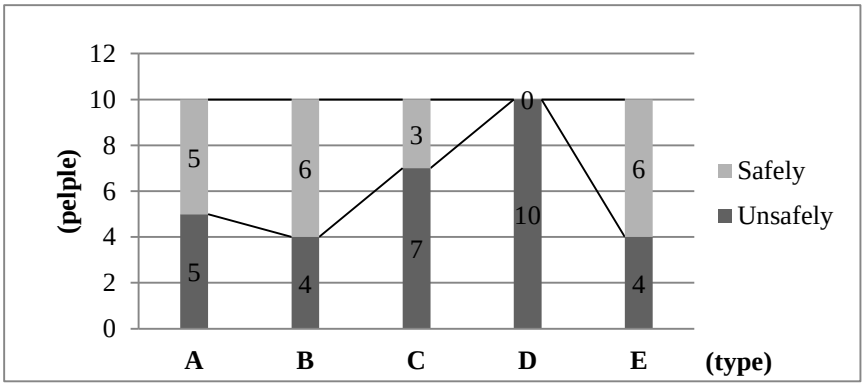

Figure.5 The propotion of pedestrians crossed the road safely or unsafely

According to Hatoyama and Shimomura (2003), determinant factors for pedestrians to decide whether to cross the roads are: the distance of the intersection, the walking speed of themselves, and the time remaining for the green light. Present study observed five common types of crosswalks in Taipei City. The distance of type A might result in mistakes of pedestrians' judgments. We also found that the time for pedestrians who stayed on the crosswalk when the red light is lit to leave the crosswalk is 7.8 seconds, which resembles the hidden seconds of type A. From this, we could know that pedestrians will refer to hidden seconds to adjust their speed and pace. But for type E, the hidden seconds are only three seconds. This is shorter than type A's 14 seconds. Thus, the proportion of safely crossing on type E is higher. Type B is a narrower crosswalk, so pedestrians can adjust the speed and estimate the distance easily. So relatively speaking, the rate of successfully crossing type B crosswalk is higher. Besides, the way to judge the distance or speed will be different for type C and type D because there are traffic islands. Traffic islands will separate the crosswalk, which make the actual distance of crosswalk shorter. Thus, pedestrians will have different judgments on the distance and will have higher possibility to stay on the crosswalks.

5. Conclusion

The value of signals is to provide more information for pedestrians to cross the roads in a safer way. However, the design of signals and the environment of intersections are closely related. Pedestrians will have different choices based on the signals and their own experiences. Because of different location or condition, pedestrian may have different behavior when crossing the roads. Therefore, we find that signal design should cater to different road types.

To sum up, the purpose of setting signals is to enhance the safety for pedestrians when crossing the roads. Thus, this research employed non-participant observation to observe five different common types of crosswalks and made the following suggestions for setting related facilities.

(1) Too many hidden seconds will let people form a habit. Pedestrians will choose to ignore the pedestrian signals and focus on the traffic lights. This is also the reason why there are still pedestrians on the crosswalk when the red light is lit.

(2) If the circulation is too long, it will make pedestrians wait for a longer time. Thus, this will cause pedestrians to cross the roads in the last seconds of the green light or just run through the red light.

(3) According to the principle of judging space-time information, small crosswalks will give pedestrians an idea that they can cross the road in a short time. This will also cause pedestrians to cross the roads in the hidden seconds.

(4) Compared to large crosswalks without traffic islands, those with traffic island will be separated by the islands. The pedestrians will adjust their judgment of space-time information based on the distance between traffic islands. We often found pedestrians trying to cross the road when there is not much time left for the green light or the red light is lit. Even there are sudden dangerous situations happening, pedestrians will react to the situations by going back to traffic islands right away.

(5) According to the observation, there will be problems when cars are turning right and the pedestrians are crossing the roads. X-shaped large crosswalks will be cleared before the pedestrians walk on them. This could solve the problem of right-turning cars and pedestrians. However, x-shape large crosswalk will make the circulation longer. This will cause pedestrians to cross the street that is the same direction with the traffic flow. If the government want to set more x-shape large crosswalks, this problem of pedestrians crossing horizontally should be taken into consideration.

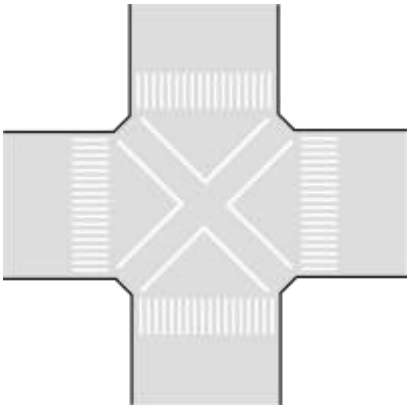

Figure.6 The X-shape large crosswalk

*According to Article 185-1 in Convention on Road Signs and Signals[6], x-shape large crosswalk will be set on intersections with pedestrian signals. Diagonal white lines will be drawn on the intersections. The width of the line is 15 centimeters. The width between two lines is three to five meters. X-shape large crosswalk is categorized into two types: all-day crosswalks or segmental ones. The period of segmental crosswalks will be drawn on the beginning of each cross lane. Take type E in this study as an example, the period of this crosswalk is from seven o’clock a.m. to seven o’clock p.m..

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