Evaluating the Effectiveness of Traffic Signs to the Drivers Approaching Level Crossings

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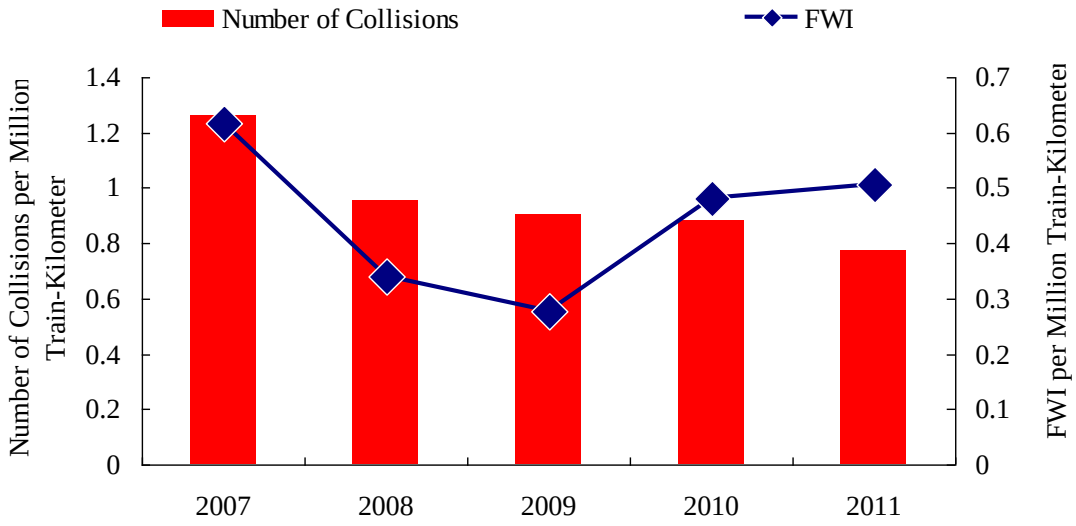
Abstract: According to historical data, most accidents at level crossings are caused by the rule-violations of vehicle drivers. To avoid these unsafe behaviors, many traffic signs are installed to alert the drivers. However, drivers can not digest too much information simultaneously and may miss important messages. It is therefore necessary to appropriately simplify and rearrange the traffic signs before a level crossing. This study carried out a questionnaire survey to the drivers approaching level crossings. We discovered three key principles to install the traffic signs: (1) It is necessary to keep cleaning and to retain the intended information near level crossings; (2) To prevent drivers' eyesight from being blocked by buildings, traffic signs should not be installed on the gantry of level crossings on curved roads; (3) Bright and shining signs are required to catch the attention on the upstream of level crossings.

Keywords: Level Crossing, Traffic Sign, Road Vehicle Drivers, Questionnaire Survey.

1. INTRODUCTION

Level crossings are the most dangerous sites in the railway systems. The collisions between trains and vehicles always lead to serious consequences, including fatalities and even social impacts. Therefore, all railway operators without exception invest much resource to improve the safety of level crossings. Taiwan Railway Administration (TRA), the operator of the conventional railroads in Taiwan, also have installed many protection devices to avoid the accidents at level crossings. At present, most level crossings in Taiwan are equipped with flashing lights (which set up a chain reaction in audible devices), and more than 90% are equipped with boom barriers. Furthermore, TRA also installed emergency buttons on the roadsides of almost all level crossings and obstacle detectors at some particularly dangerous sites.

However, the protection devices have less and less effectiveness in reducing the collisions. Fig. 1 shows the safety trend of level crossings in recent years in Taiwan. The number of collisions has declined gradually, but the number of fatalities and weighted injuries (FWI) has increased since 2010. The main reason is that the proportion of motorcycle crashing with train increased in 2010 and 2011. Moreover, the figure also shows that the number of collisions declined slowly after 2007. Fig. 2 categorizes the causes of collisions. It shows that "inadequate driving behaviours" accounts for 77% of all causes of collisions at level crossings. Among them, over 70% are resulted from the law-violating behaviours (trespass, and without keeping enough gap from the leading vehicle), which can not be avoided by protective devices. It means the protective devices that TRA had installed may at most reduce 40~50% collisions in the future, if TRA does nothing to avoid the law-violating behaviours.



*1 Injury = 0.1 Fatality.

Figure 1. The safety trend of level crossings in taiwan

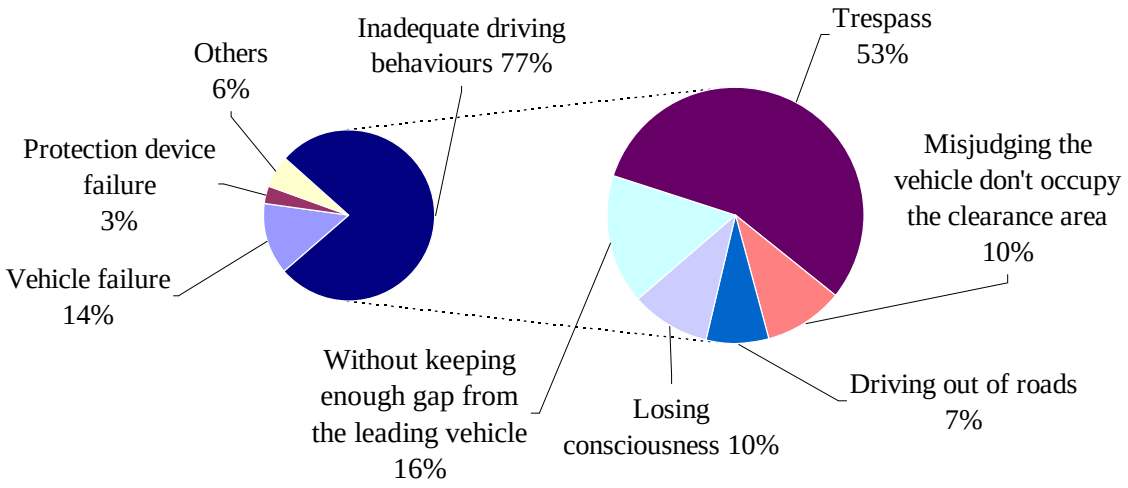


Figure 2. The causes of collisions at level crossings in taiwan

In fact, the Taiwan government had implemented many measures to prevent drivers from violating traffic laws (e.g., increasing the amount of fines for trespass). TRA has also started an experimental plan on a level crossing to reduce the violations since 2011. In the experimental plan, TRA has adopted the following improvement measures: (1) increased the evidence of level crossings by painting yellow and black stripes on the gantry; (2) set up warning signs to remind drivers that the level crossing is installed with CCTV. Once drivers trespass the level crossing, they will be captured by CCTV and will be fined heavily; (3) installed train direction indicators on the gantry; (4) set up guiding signs to remind drivers what they should do once their cars are trapped at level crossings; and (5) deployed security personnel to guide traffic. Fig. 3 shows the before and after pictures of the level crossing.

The experimental plan indeed decreases the frequency of violations, but the effectiveness of individual measure is still unknown. Fig. 4 shows the number of broken boom barriers (which is the leading indicator of collisions) before and after the experimental plan. It is obvious that no barrier is broken after the plan. However, some drivers criticized the information on traffic signs for being too much to understand. For these reasons, the purpose

of this study is to understand the feeling of road vehicle drivers while approaching this level crossing through questionnaire surveys. We also investigated two other level crossings, which are a little different from the experimental one, to compare the results in different environments. According to the outcomes of the surveys, TRA can conclude which information is useful and should be retained, and which is useless and should be canceled.

Before

After

Figure 3. Before and after pictures of the experimental level crossing

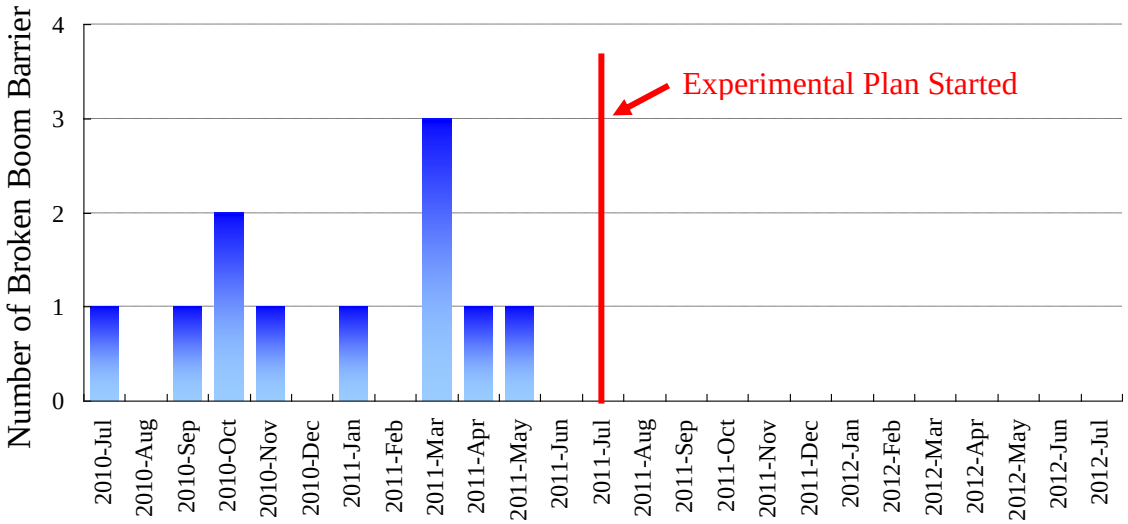


Figure 4. The performance of the experimental plan

2. Literature Review

The causes behind drivers violating regulations and even trespassing are mainly ascribed to human factors. Dixon (2007) concluded that eight human factors may result in violations or error behaviours through literature reviews, level crossing visits, signal box visits, and interviews. These human factors include: competence, distraction, inadequate design, individual perceived control, risk compensation, familiarity, complacency, and mental models. Among them, the distraction and inadequate design are the main causes leading to violations. It means that road vehicle drivers would be unaware of the warnings or not aware of dangers, if the traffic signs are installed on the wrong locations or designed inadequately.

Pickett and Grayson (1996) analyzed the data taken from drivers who had been observed violating activated warning systems at level crossings. They found that 13% of the drivers trespassed across level crossings because their speed is too fast to stop before the stop line, or because someone is driving too close behind. 27% of the drivers claimed to be unaware of either the crossing or the lights, because they were inattentive or were distracted. The findings represent almost 40% of the violations could be avoided, if the warning signs before level crossings are attractive and indeed remind the drivers to decelerate and keep at a safe distance behind the leading vehicle. The same findings were also shown in the Australian Rail Safety Occurrence Data (ATSB, 2009). Almost half of fatal level crossing crashes in Australia were caused by unintentional errors. It means the drivers may fail to perceive the warnings or apprehend their meanings, even if the site is known and the warnings are clearly visible.

To increase the effectiveness of warning signs, many researchers studied human characteristics, environments, locations of signs, and the limit of information. For example, Chen *et al.* (2008) used the change blindness method to investigate the cognitions of drivers with different characteristics. They found that older drivers clearly have longer response time than younger ones. In their experiment, less information (signs, signals, and pedestrians) results in a higher accuracy rate in judging the difference. Borowsky *et al.* (2008) experimented with 20 drivers reacting to practical traffic signs. The experiment showed that the drivers are less likely to identify the traffic signs when the signs are located at the unexpected locations. Crundall and Underwood (2011) concluded that the information should be simplified for the inexperienced drivers based on the results of eye tracking method. Liu *et al.* (2011) also used eye tracker to study drivers' visual cognition behaviors of traffic signs, and concluded that the amount of traffic guide signs should not exceed 5 to avoid increasing fixation duration.

The issues of traffic signs become complex when road vehicle drivers approach level crossings. Lenne *et al.* (2011) introduced the "on-road test vehicle" to collect the vehicle data (speed, braking, steering wheel angle, lane tracking etc.) before approaching level crossings. It was concluded that the locations of signs, roadway design, actions required after level crossings, surrounding traffic, and pedestrians are important factors for the safety of level crossings. Among them, rearranging the locations of signs is the easiest improvement measure for roadway and railway administrators. However, it is very difficult to identify the individual impact of traffic signs on the drivers' behaviours based on the observed data. Therefore, this study tries to capture the effectiveness of individual signs on drivers through questionnaire survey.

3. Research Method

This section illustrates three selected level crossings being investigated, the procedure of survey, and the questions in the questionnaire.

3.1 Selected Level Crossings

Because we did not survey road vehicle drivers before the experimental plan, two other level crossings near the experimental one were selected to be a control group. These three level crossings have similar protective devices. They are all installed with automatic barriers, closed-circuit television camera (CCTV), emergency buttons, and flashing lights. Moreover, the roads connected to these three level crossings are all two-lane roads. However, the environments around the three level crossings are slightly different. Especially after the experimental plan, many improvements were implemented at the experimental level crossing. Tab.1 compares these three level crossings and illustrates differences. The differences help us explain the result of questionnaire survey in following sections.

Table 1. The comparisons among three level crossings

Name	A	B	C
Picture			
Gantry Color	Yellow-Black Stripes	Orange-Black Stripes	No Stripes
Train Direction Indicator	Yes	Yes	No
Warning Sign	Yes	No	No
Guiding Sign	Yes	No	No
Security Personnel	Yes	No	No
Near Buildings	Numerous Buildings	Some Buildings	Few Buildings
Road Curve	Straight	Curved	Curved
Road Slope	Flat	Flat	Uphill

3.2 Survey Procedure

To make the surveys go smoothly and to reduce the impacts on road users, we only surveyed the first vehicle approaching level crossings when the flashing lights started to shine. The procedure of survey is described as follows:

1) Two investigators were deployed at both sides of a level crossing.
2) When the flashing lights started to shine, investigators would target the first vehicle approaching the level crossing.
3) We only surveyed the vehicle that was within 100 meters before the level crossing while the flashing lights started to shine.
4) When the vehicle stopped before the stopping line, the investigator would walk to the driver and start the survey.
5) The survey was carried out from A.M. 9:00 till P.M. 8:00.
6) We carried out the survey in three days including one weekend day and two working days. The weather was sunny and cloudy.

7) We only surveyed cars and motorcycles.

3.3 Questionnaire

The questionnaire only has three questions concerning the cognition of drivers, and the respondents can choose from the multiple options for each question. Since the environments around three level crossings are a little different, we designed three questionnaires with the same questions but different options. These three questions are:

1) Which information made you discover the level crossing?
2) Did you notice any following information on the gantry before you arrive at the level crossing?
3) Had you seen any following information before you approached the level crossing?

The first question wants to know the critical information making drivers brake and stop. The second checks the noticeability of individual information on the gantry. The purpose of the last question is to understand the effectiveness of pre-warning signs which alert drivers to decelerate and to notice the level crossing. All options are in colourful pictures to ensure that the respondents can complete the survey in 30 seconds, because the shortest closing time of level crossings is 30 seconds. Fig. 5~ Fig. 7 are the options for the three questions.

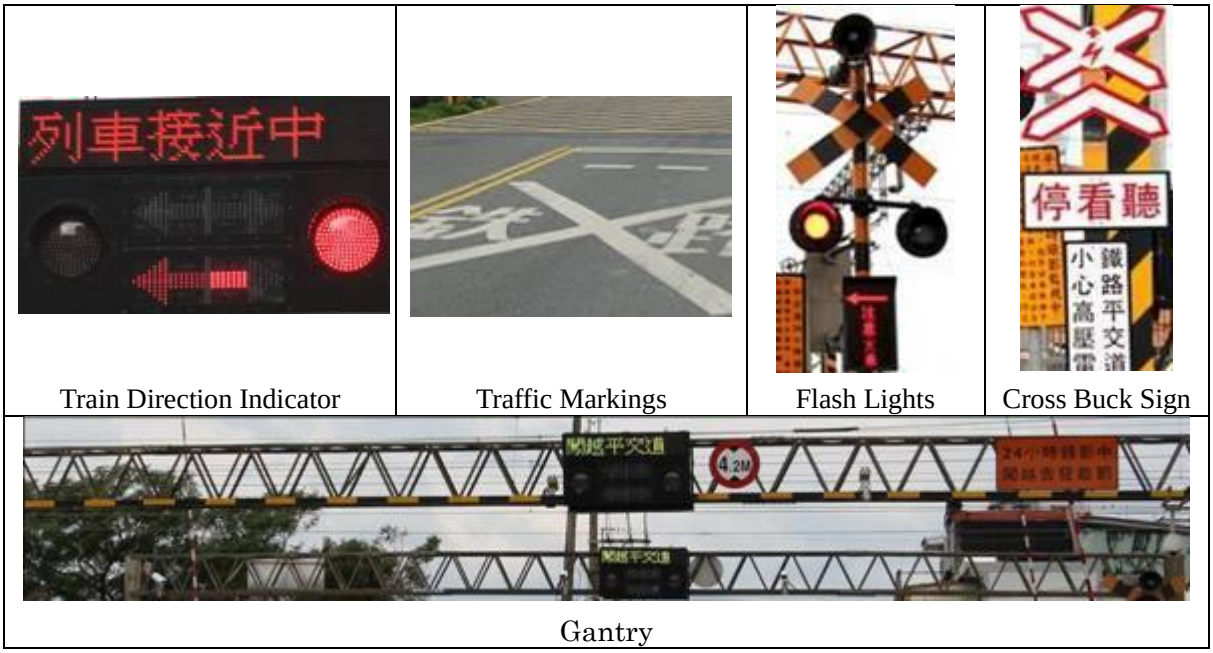
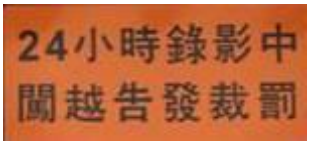


Figure 5. The options for the first question

Guiding Sign

Low Clearance Sign (Circle)

Low Clearance Sign (Rectangle)



Warning Sign

LED Changeable Message Sign (CMS)

Figure 6. The options for the second question

Level-crossing Sign

Maximum-speed-limit-Sign

Warning Sign

Figure 7. The options for the third question

4. Results of Questionnaire Survey

Tab. 2 shows the number of effective questionnaires that we surveyed during three days. The sample sizes of cars are not enough at level crossing B and C during nighttime, and all sample sizes of motorcycles during nighttime are also not enough. Therefore, we could only analyze the cognition of car drivers at level crossing A during nighttime. This section sequentially illustrates the result of the three questions.

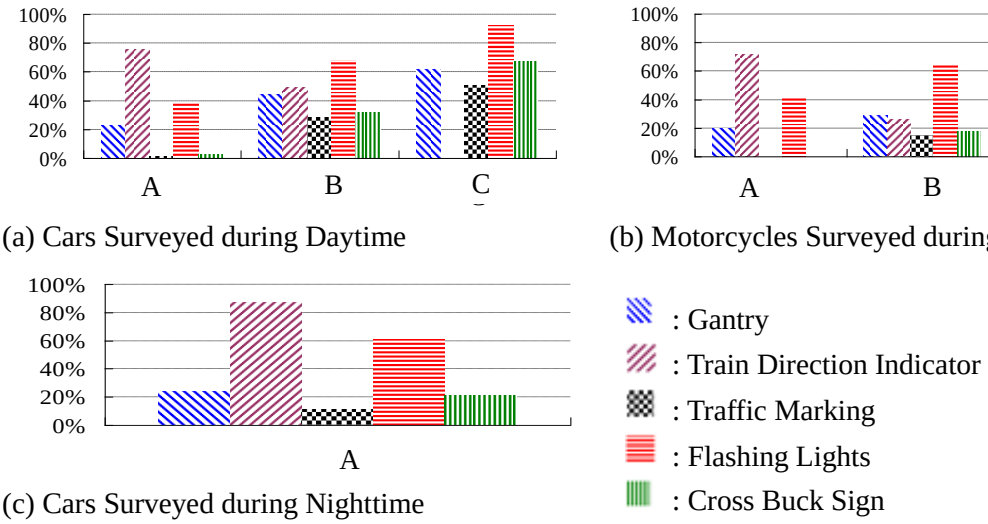
Table 2. The number of available questionnaires on each level crossing at different times

Vehicle Type & Time / Level Crossing	Cars		Motorcycles	
	Daytime	Night	Daytime	Night
A	183	38	46	12
B	84	13	62	8
C	126	6	43	4

4.1 Results of the First Question

Fig. 8 shows the result of the first question: Which information makes you discover the level crossing? The horizontal coordinate represents three level crossings, and the vertical coordinate means the percentage of all drivers choosing the answers to this question (The meanings of coordinates are the same in Fig. 9 and Fig. 10). Because redpondents can choose more than one option, the total percentage of answer for a level crossing may over

100%.Among the three level crossings, C is not installed with train direction indicator, and thus, the options in C do not include it.



(a) Cars Surveyed during Daytime

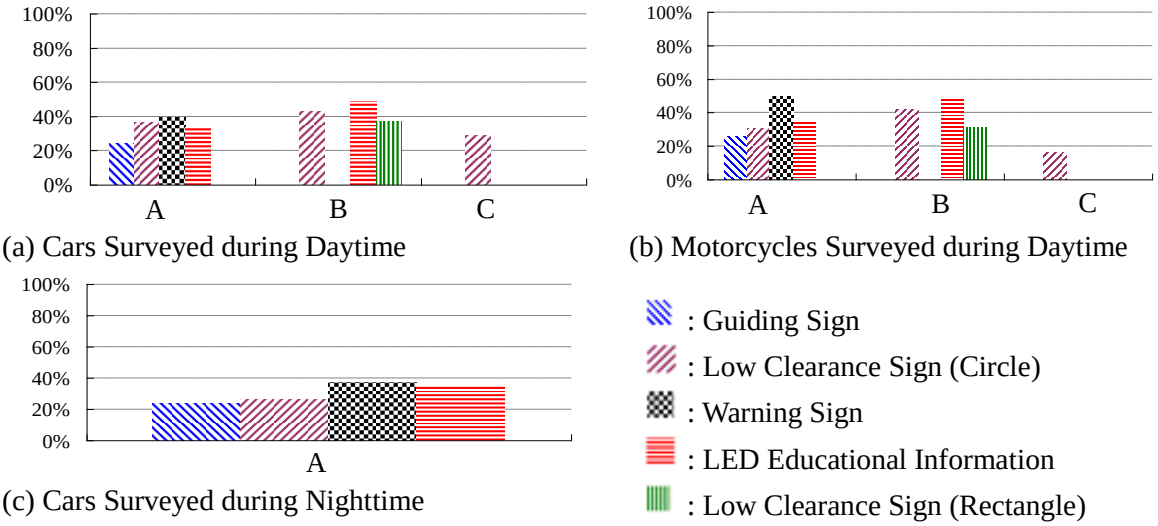
(b) Motorcycles Surveyed during Daytime

(c) Cars Surveyed during Nighttime

Figure 8. The results of the first question

4.2 Results of the Second Question

Fig. 9 shows the result of the second question: Did you notice any following information on the gantry before you answer this question? It should be noted that the guiding sign and the warning sign are only installed at level crossing A. The low clearance sign (rectangle) is only set at level crossing B. Level crossing C only has low clearance sign (circle). The results of this question can reflect the effectiveness of the signs installed on the gantry. TRA could simplify the information based on the results.



(a) Cars Surveyed during Daytime

(b) Motorcycles Surveyed during Daytime

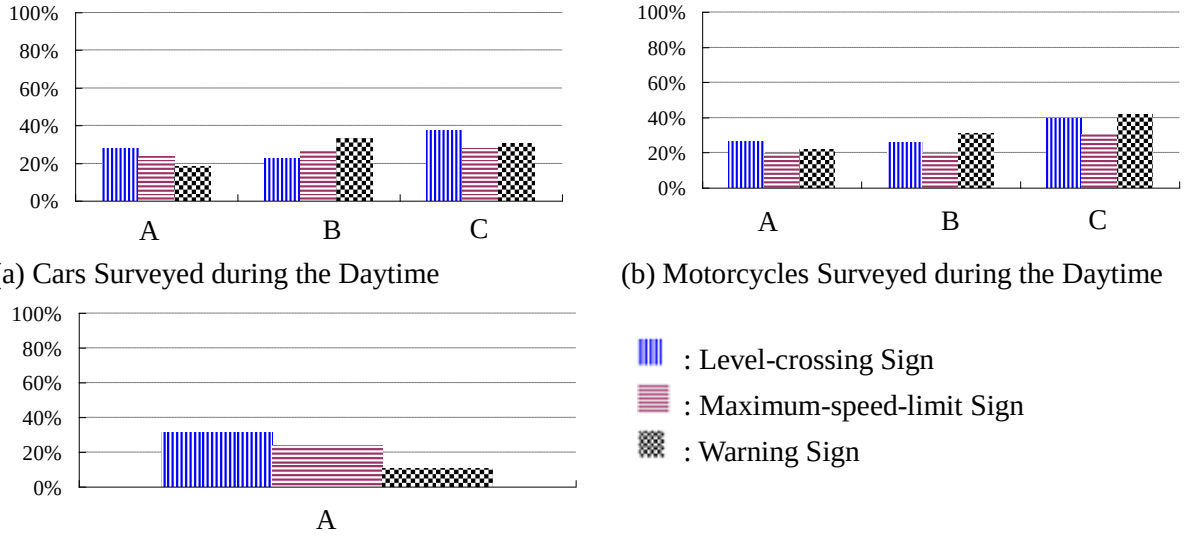
(c) Cars Surveyed during Nighttime

Figure 9. The results of the second question

4.3 Results of the Third Question

Finally, Fig. 10 shows the results of the third question: Had you seen any following information before you approached the level crossing? According to the laws in Taiwan, both the level-crossing sign and the maximum-speed-limit sign should be placed before level

crossings. If the level crossing is installed with CCTV, the warning sign is also needed. Since the three level crossings being surveyed are all installed with CCTV, the third question for all respondents at the three level crossings includes three options, i.e., the level-crossing sign, the maximum-speed-limit sign, and the warning sign for CCTV. The purpose of this question is to check the effectiveness of pre-warning signs on the upstream of level crossings.



(a) Cars Surveyed during the Daytime

(b) Motorcycles Surveyed during the Daytime

(c) Cars Surveyed during the Night

Figure 10. The results of the third question

5. Findings

According to the results of the questionnaire survey, we summarized five key findings in this section.

1) While the environment is more complex, drivers rely on simpler signs/messages to judge whether they approach a level crossing.

Among the three level crossings, level crossing A is the most complex one, B is the second, and C has the least information. Reflecting the difference of complexity, Fig.8-(a) shows an interesting phenomenon. The traffic marking is the least attractive message among all options in the first question. However, there are still 51% of the drivers discovering level crossing through the traffic marking at level crossing C. The percentage at level crossing B decreases down to 29%, and it is only 1% at level crossing A. Moreover, the same trend occurs on the percentages of gantry, cross signs, and flashing lights. Only the train direction indicator at level crossing A attracts more drivers' attention than at level crossing B (Train direction indicator is not installed at level crossing C). The results imply that drivers would focus on **simpler signs/messages** to judge whether they approach a level crossing in a complex environment. For example, most road vehicle drivers only rely on train direction indicators and flashing lights at level crossings A. On the contrary, most drivers approaching level crossing C could receive all information to judge whether they approach a level crossing.

2) The information on the gantry is more noticeable to road vehicle drivers on straight roads than on curved roads, and the information on the roadside is quite the contrary, especially to the motorcycle riders.

Tab.1 shows that only the crossing road at level crossing A is straight; those at both level crossings B and C are curved roads. Fig.8 has already shown that the train direction indicator and flashing lights are the two most noticeable messages. One of them is installed on the gantry, while the other is located on the roadside. Tab.3 compares the percentages of drivers who discover the level crossings via these two messages. It is apparent that flashing lights attract more road vehicle drivers on curved roads than on straight roads. On the contrary, the percentage of train direction indicator on straight roads is higher than that on curved roads. The phenomenon is more significant to motorcycle riders than vehicle drivers.

Table 3. The percentage of drivers who discover the level crossings

Level Crossings & Information Type / Vehicle Type	A (Straight Road)		B (Curved Road)		C (Curved Road)	
	Train Direction Indicator (Gantry)	Flashing Lights (Roadside)	Train Direction Indicator (Gantry)	Flashing Lights (Roadside)	Train Direction Indicator (Gantry)	Flashing Lights (Roadside)
Car	75%	39%	49%	68%	N/A	94%
Motorcycle	72%	41%	26%	65%	N/A	98%

3) The gantry attracts more attentions in spacious environment; the complexity of environment indeed affects the cognitive ability of drivers.

The result of questionnaire survey also confirms the findings of past studies (Chen, 2008; Crundall and Underwood, 2011): drivers can easily miss messages and respond slower in a complex environment. Tab.4 shows that most drivers can notice the gantry at level crossing C, even though the gantry at level crossing C is the only one which is not painted in colorful stripes. We think the result is due to the spacious area around level crossing C. Tab.5 also demonstrates the advantages to simplify the information. It shows that almost no driver discovered level crossing A by cross buck signs. However, the cross buck sign is the most important and popular message in Taiwan to alert drivers that they are approaching a level crossing. Fig.11 explains why drivers are not aware of the cross buck signs while approaching level crossings A and B. The complex backgrounds at level crossings A and B confuse the drivers when they try to distinguish the cross buck signs.

Table 4. The percentage of drivers who discovered the level crossings by gantry

Level Crossing / Vehicle Type	A	B	C
Car	22%	44%	62%
Motorcycle	20%	29%	51%

Table 5. The Percentage of Drivers Who Discovered the Level Crossings by Cross Buck Signs

Level Crossing / Vehicle Type	A	B	C
Car	2%	32%	67%
Motorcycle	0%	18%	70%

Level Crossing A

Level Crossing B

Level Crossing C

Figure 11. The complexity of environment at three level crossings

4) The messages on the gantry are usually unnoticed except for the message with similar colors to the speed camera signs.

Tab.6 compares the effectiveness of different messages on the gantry. In the table, no matter which message drivers notice, the percentage is less than 40% except for the warning sign to the motorcycle riders. In fact, the warning sign noticed by the car drivers is also almost 40% (39%). The data demonstrate that the warning sign is the most noticeable message on the gantry. We think the main reason is that the colors of waning signs are similar to the speed camera sign. Once the drivers notice the colors, they will decelerate intentionally and then focus on the sign to check the words on it.

Table 6. The percentage of drivers who noticed the messages on the gantry

Information Type on the Gantry / Vehicle Type	Daytime				Nighttime			
	Guiding Sign	Low Clearance Sign	Warning Sign	LED CMS	Guiding Sign	Low Clearance Sign	Warning Sign	LED CMS
Car	24%	37%	39%	34%	24%	26%	37%	34%
Motorcycle	26%	30%	50%	35%	N/A			

5) Pre-warning signs on the upstream of level crossings are usually unnoticed.

Tab.7 shows that information on the upstream of level crossings is usually unnoticed. Even the warning signs (which have similar colors to the speed camera sign) only attract 11%~33% of the drivers except for the motorcycles approaching level crossing C. The higher percentage at level crossing C may be attributed to the spacious area around the level crossing.

Table 7. The percentage of drivers who discover the pre-warning signs

Level Crossing & Vehicle Type / Pre-warning Sign Type	A				B		C	
	Daytime		Nighttime		Daytime		Daytime	
	Car	Motor-cycle	Car	Motor-cycle	Car	Motor-cycle	Car	Motor-cycle
Level-crossing Sign	28%	26%	32%	N/A	23%	26%	37%	40%
Maximum-speed-limit Sign	23%	20%	24%		26%	19%	28%	30%
Warning Sign	18%	22%	11%		33%	31%	30%	42%

6. Conclusions

According to the findings, this study concludes three recommendations for TRA.

1) **It is necessary to simplify the information and retain the noticeable and simpler messages.**

A complex environment makes drivers miss information which is important to them. In this study, we found that the signs with similar colors to speed camera signs could attract the most attention, and the guiding signs are usually missed. Therefore, we recommend TRA retain the warning signs and remove the guiding signs from the gantry.

2) **The signs should be located on the roadside of curved roads and on the gantry on straight roads.**

Although the information on the gantry can be noticed easily, it may be blocked by buildings especially on curved roads. The result of questionnaire survey also shows that more drivers are aware of roadside information than the information on the gantry on curved roads. Moreover, the cost to install and maintain the signs on a gantry is higher than that on the roadside. Therefore, it is recommended that TRA install the signs on the roadside of curved roads and on the gantry on straight roads.

3) **The pre-warning signs on the upstream of level crossings should be installed with flashing LED or be painted with bright colors to attract the attention of drivers.**

Generally, the drivers focus on the center of eyesight and have higher probability to miss the information on the roadside. To alert the drivers, we recommend that the signs on the upstream of level crossings be installed with flashing LED to attract the attention of drivers. Painting with bright colors is another low-cost method to enhance the noticeability of pre-warning signs.

Since this study was carried out after the experimental plan, we did not have the complete before-and-after data to analyze drivers' behaviors. In the future, TRA will select certain level crossings to implement the recommendations in this study. We plan to carry out a before-and-after questionnaire survey to evaluate the effectiveness of the recommendations. The findings in this study may be further verified. The other important issue behind this study is that even though drivers notice the signs, they may not understand the meanings. It needs a further study to judge whether drivers are aware of the signs as well as know what to do under the circumstances. In such scenario, situation awareness global assessment technique (SAGAT) (Endsley, 1995) is an alternative to explore the issue.

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