# Requirements for Comprehensibility of Graphic Symbols
## Based on Japanese expressway information board

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**Abstract:** This study showed the requirements for comprehensibility of graphic symbols, which are important to convey the information. Japanese expressway information board was taken as an example. The condition of existing symbols was observed by the degree of comprehension and impression of comprehensibility. As the result, evaluation of impression indicated that white and reappearance color of multi-colors display are significant for comprehensibility. Both results of the observation indicated that most of the symbols using car picture required to be improved. Accordingly, requirements of comprehensible symbols using car picture were extracted, influence level of the requirements was determined by analysis of Quantification 1. Requirements were verified by pair comparison method between trial samples and existing graphic symbols. This study concluded that the main requirement is to present a clear relationship between event and car, in case of using the car picture as a part of symbol. Therefore, expression of car motion in cause and consequences has effect. Moreover, it can be said that when the car motion is cleared whether it is moving or stop, the event detail is explained well; and when the event detail is explained, the subject of car in symbol will be cleared.

***Key words: Graphic symbol, Comprehensibility, Information board, Car picture, Expressway***

## 1. Introduction

Graphic symbols that established as traffic signs are learned in advanced during the driving license acquisition. On the other hand, there are many graphic symbols as a danger warning, aside from traffic sign. This graphic symbols needs to be comprehensibility even when it is seen for the first time. It is remarkable in expressway, where requires instant clarification of the information while being burden by driving.

Graphic symbols that are displayed in expressway information board [1][Figure 1] play significance role [2], which are as a prediction and a complement to the text, and as conspicuity. Furthermore, graphic symbols are main element as comprehensible information of unfamiliar driver or foreigner. In Japan, improvement plan towards comprehensible graphic symbols is required, based on the changes of styles, which are display colors and data controlling system [3] of expressway information board in recent years.

This study discussed requirements for comprehensibility of graphic symbols, based on Japanese expressway information board. Survey 1 (testing) and survey 2 (evaluation of impression) were aimed to extract and analyze the influence level about requirements for comprehensibility of graphic symbols. Requirements were verified by comparison between trial samples and existing graphic symbols.

Besides, the main indexes for comprehensibility of graphic symbols are accuracy of comprehension (similar understanding among many people) and comprehension in a short time [4]. This study focused on the accuracy of comprehension.
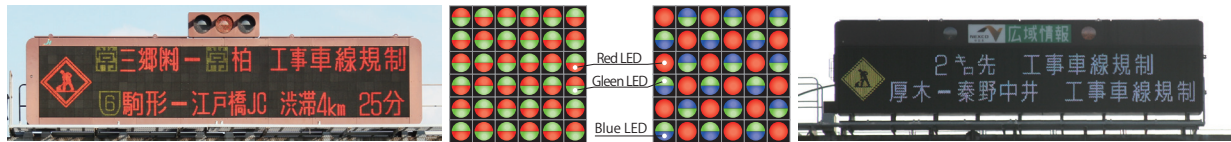
Figure 1  Japanese Expressway Information Board with Symbol, and LED's Arrangement
(Left:3-colors display, Right:Multi-colors display)

## 2. Survey 1: Testing for Comprehension of Graphic Symbols

The purpose of this survey was to evaluate the degree of comprehension for a driver who has no knowledge about graphic symbols.

### 2.1. Testing Method

In 2001, Foundation for Promoting Personal Mobility and Ecological Transportation did a test about the comprehension of public information graphic symbols [5], by dividing it into several categories such as safety, prohibition, cautions, and directions. This was a method of choosing the correct answer from 4 choices (JIS S 0102).

In this study, basic scoring system [Table 1] and evaluation for classification acceptation [Table2] were based on categories of JIS S 0102. However, the answer was based on free description (ISO9186). There are 2 reasons, the first was that this survey should evaluate in detail about the respondent's comprehension. The second was that the graphic symbols in the information board which do not have specific for shape, border and color [Figure 2].

### 2.2. Sample Selection

Sample was taken from the graphic symbols that display in Tomei Expressway. Number of dots was 128 for length and 96 for width in a high flexibility. There were 19 samples of 3-colors display because in the pre-testing

Table 1 Basic Scoring System

| Comprehensibility level | Standard classification | score [points] |
|---|---|---|
| 1. Correct answer | It is the term that tell the meaning of the symbol. | 100 |
| 2. Incorrect answer 1 | It is the term for the symbol that is not understood correctly, with at least can avoid the action that contrary with the display person intention. | 60 |
| 3. Incorrect answer 2 | It is the term that considered when the message regarding safety, prohibition, cautions and direction are well understood, but unable to understand the meaning of the symbol. Thus, it is considered for unable to avoid the action that contrary with the display person intention. | 30 |
| 4. Incorrect answer 3 | It is the term that considered when the message regarding safety, prohibition, cautions and direction are miss understood, making it difficult to understand the meaning of the symbol. Thus, it is considered for unable to avoid the action that contrary with the display person intention. | 0 |
| | When there is a declaration of miss-understand intention such as unknown and false. | 0 |
| | No reply [when completely no reply on the sheet] | Exclude |

Table 2  Evaluation for Classification Acceptation

| Evaluation score | Improvement plan |
|---|---|
| 85 points and above | Degree of comprehensibility is high and acceptable |
| Below 85 points 66 points and above | Acceptable when awareness of "necessary to present with supplementary text explanation" is atttached |
| Below 66 points | Re-examine the overall related item |

of 3-colors and multi-colors displays showed there was no difference in score. Display colors of sample were obtained on RGB ratio from the previous research [6] which use the visibility distance in relative difference.
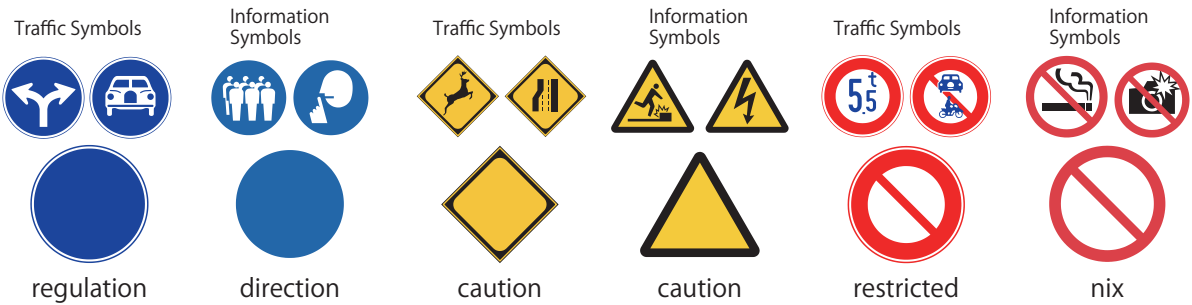
| Traffic Symbols | Information Symbols | Traffic Symbols | Information Symbols | Traffic Symbols | Information Symbols |
|---|---|---|---|---|---|
| regulation | direction | caution | caution | restricted | nix |

Figure 2  Japanese General Signs and Standard Design

## 2.3. Testing Respondent

Respondents of this survey were driving license holder that understand the traffic regulation. The reason was that information communicates well to the driver. However, expressway frequency usage is limited to the 2 times or less per year. This was because it was best to choose the respondents who able to interpret graphic symbols without the prior study. There were 42 respondents in the early 20's who are 32 males and 10 females.

## 2.4. Testing Outline

Each sample with the size of 185 mm width and 140 mm length were displayed using 42-inch monitor, which was placed 2 m away from the respondent [Figure 3]. Firstly, the respondent was explained regarding the graphic symbols in expressway information board and the example answer. Next, all the 19 samples were displayed in random in a second (1s) time duration. Then, respondent described about the "meaning of event " and the "action which should be taken", with no restriction by the number of answer.
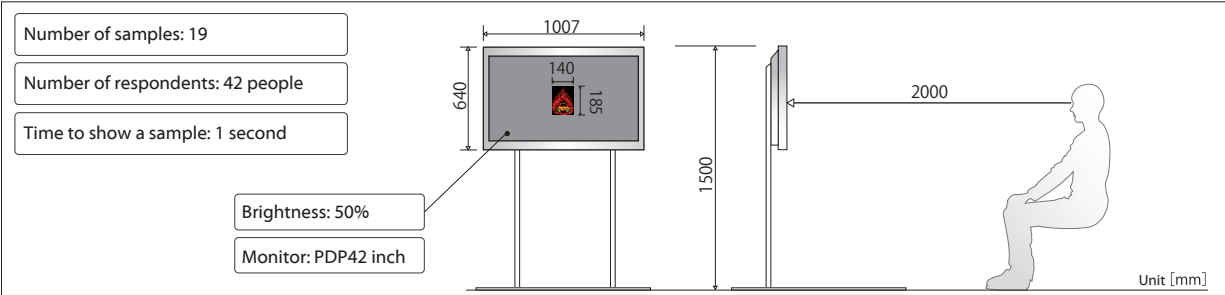
Number of samples: 19
Number of respondents: 42 people
Time to show a sample: 1 second
1007
140
185
640
1500
2000
Brightness: 50%
Monitor: PDP42 inch
Unit [mm]

Figure 3 Testing Outline

## 2.5. Formation of Score

The degree of comprehension was done by verbal discussion by 3 persons according to the evaluation basic in Table 1 regarding the "meaning of event" and, the "action that should be taken".

## 2.6. Result

Result is shown as in figure 4 arranged in decrease score order based on the degree of comprehension. In this study, event names of graphic symbols are expressed by the detail meaning.

The general danger warning signs such as the 'roadwork ahead', 'road close' and 'disaster (falling rocks)' were seen during the driving license acquisition, or can be seen in a general street in many cases. Therefore, the high score of comprehension degree can be said obtained by the familiarity. Then, 'rain', 'snow', 'high waves' were as

the phenomenon also showed the high score because it is familiar in the weather report. On the other hand, for the points below 66 correspond to the 5 graphic symbols, improvement was needed. These 5 graphic symbols all have one in common, which is the picture of a car.
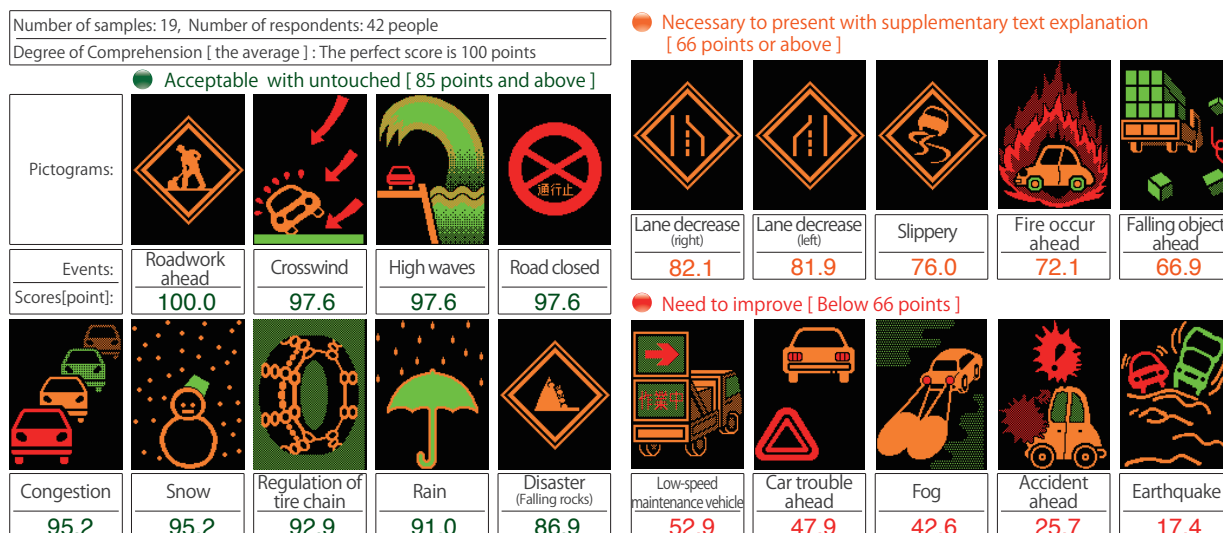


Figure 4 Degree of Comprehension

## 3. Survey 2: Evaluation of Impression about Comprehensibility of Graphic symbols

Survey 1 was the testing for degree of comprehension. For survey 2, the evaluation of impression displayed the graphic symbol with text. The text was to show the event and its detail meaning. In relation, multi-colors display was added to the 3-colors display [Figure 5] to establish if there is any difference or not.



Figure 5 Multi-colors Display Symbols

### 3.1. Evaluation Method

Five Likert scale to evaluate the comprehensibility were prepared such as 'high: 10 point', 'moderately high: 7.5 point', 'neither: 5 point', 'moderately low: 2.5 point' and 'low: 0 point'.

### 3.2. Sample Selection

Sample selection was similar with the survey 1 which is displayed in Tomei Expressway. There were 38 kinds of samples (19 samples for 3-colors, 19 samples for multi-colors) that have similar condition for survey 1 in terms of the number of dot and size.

### 3.3 Evaluation Respondent

21 persons (male: 18 persons, female: 5 persons) in the early 20's were the respondents whom hold the driving license and have low frequency of expressway usage.

### 3.4. Evaluation Outline

The samples with text were displayed. The text was to show the event and its detail meaning. There was no restriction presentation time. Others conditions were similar with the survey 1.

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## 3.5. Result

Scatter diagram to represent result is shown in figure 6. Horizontal axis is for 3-colors display and vertical axis is for multi-colors display. The result of 3-colors display is shown on the diagonal line. Most remarkable tendencies are shown in figure 7.

Score that positioned above the diagonal line which is in increasing direction is represented the improvement by multi-colors display, especially the 'rain', 'snow', 'crosswind', 'fog' and 'disaster (falling rocks)' showed the significant improvement. On the other hand, score below 6 points were seem that the improvement is needed, such as 'earthquake', 'accident ahead', 'low-speed maintenance vehicle', 'fog', 'car trouble ahead', 'falling object ahead' and 'fire occur ahead'. These graphic symbols have common figure, which is the picture of a car. From this result, it can be said that survey 1 and survey 2 has the similarity.
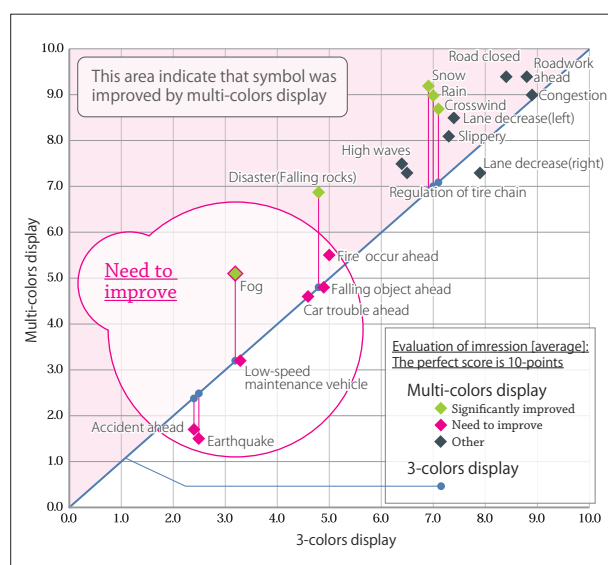


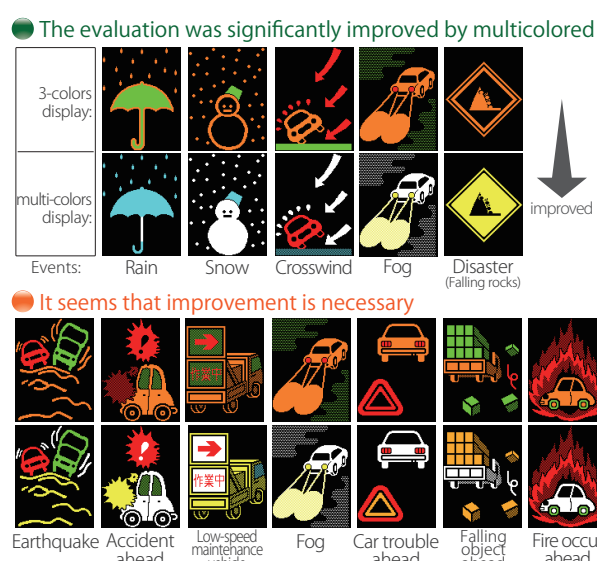Figure 6 Map for Impression of Comprehensibility



Figure 7 Remarkable Tendancies

## 4. Deliberation of Requirements for Comprehensibility of Graphic Symbols

The result from survey 1 and survey 2, graphic symbols that need improvement have common picture of car. Due to that, extraction of requirements for comprehensibility was done, so that the car picture as an image item in graphic symbol can be used.  Then, the analysis of Quantification 1 was done to evaluate the influenced level of requirements.

## 4.1. Extraction of Requirements from Discussion in each Survey 1 and 2
### Survey 1

'Cross wind' is considered as unfamiliar graphic symbol relatively of all graphic symbols. However, since the degree of comprehension was high as 97.6 points, its expression technique using the car picture as an image item can be a reference. The composition was closely checked based on the image items. When the composition was checked, the direction is follow by the movement of cause and consequences; for example 'a strong wind blows', 'a car inclines' and 'a car breaks out in a cold sweat' [Figure 8.1].

From this expression, the requirements for comprehensibility can be forecasted from following matter:

1) Influence of an event is by a motion of a car in a dynamic expression: 'motion of a car'

2) Expression of movement relation in cause and consequences: 'cause and consequences relation'

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The expression of cause and consequences is one of the verb expression indexes, which is proposed by Ono et al. [7]. This idea is also referred in specific context as expressway.

In survey 1, there were many unknown and false answers such as 'earthquake', 'accident ahead', 'fog' and 'fallen object ahead' as in figure 8.2. It can be said that other image items are greatly expressed to the item which represent the event, such as 'lights of fog', 'ground of earthquake' and 'truck of falling object ahead', etc. For the 'earthquake', the wavy line is interpreted as bump sign and the vibration line is interpreted as the wavy line that shakes with the car movement. In relation, for the 'falling object ahead', there were many false answer such as "a load is need to firmly fix to prevent falling object" and "a cautions of over loading".

When the text cannot be interpreted correctly, the driver will not act as warned. Miss understanding of the subject about the car subject in the graphic symbol will result as different interpretation such as "collision caution of accident ahead", "caution for fire origin of fire occur ahead", etc.

As mentioned above, the accurate interpretation of requirements are needed as below:

3) Relation between an event and a car is shown clearly: 'clarification of relation'

4) Subject of a car in graphic symbol is shown clearly: 'clarification of a subject'

Then, common feature for the low score of graphic symbols will be mentioned in viewpoint direction as below. For example, 'low-speed maintenance vehicle', 'fog', 'falling object ahead', were drawn from the bird-eye view or slant view that 3D expression is complicated. Therefore, when the direction of a car and viewpoint of driver are changed, the relationship between car picture and driver can be clearly expressed.

Then, next matter is added as requirements.

5) Position of a viewpoint is clarified according to an event: 'clarification of a viewpoint'

**Survey 2**

Result for score average was analyzed by ANOVA, which the p-value < 1%, multi-colors display was significantly different from 3-colors display.

As mentioned before in survey 2 result, graphic symbols for phenomenon or general traffic sign that were reproduced according to the nearest of the actual color, resulting in improvement of comprehensibility. Hence, it can be said that one of the requirement for improvement of the comprehensible graphic symbols is reproduced using color. Moreover, multi-colors display became distinguishable between images items have influenced to the improvement of evaluation. Especially for graphic symbols that are using white color, high luminosity and neutral impression contributed to the high distinguish between image items.

Contrary to this, the over numbers of items and colors; and difficult in relation between image resulted to the low evaluation [Figure 8.3]. The requirement for comprehensibility is as follow.

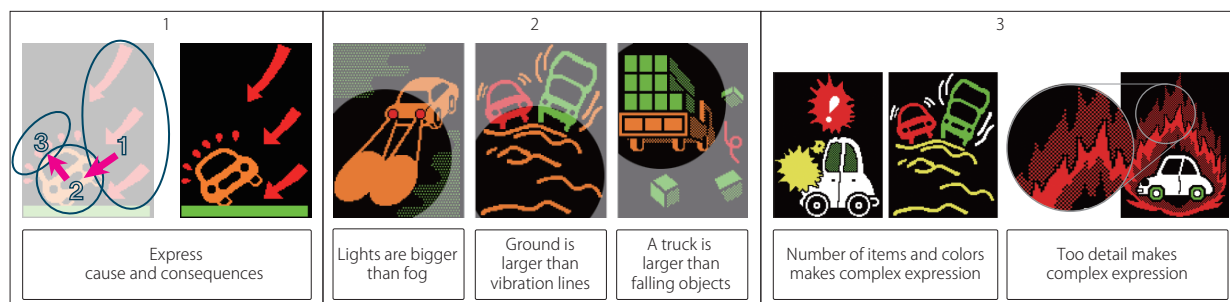6) Fine and complicated drawing is avoided: 'concise in expression'



Figure 8  Example of Requirement Explaination

## 4.2. Analysis of Requirements by Quantification 1

Score of each survey 1 and survey 2 were selected as the response variable in Quantification 1 analysis to observe the influence level for extracted requirements. Explanatory variable for survey 1 were 6 items such as 'clarification of relation', 'cause and consequences relation', 'clarification of a subject', 'motion of a car', 'concise in expression', and 'clarification of a viewpoint'. In regards to it, in survey 2 there were 6 items, which are 'clarification of relation', 'motion of a car', 'concise in expression', 'clarification of a subject', 'clarification of a viewpoint', and 'display color'. Display color was added to the explanatory variable to determine the difference on how much it's contribute to the comprehensibility of graphic symbols. There were 10 samples for survey 1 and 20 samples for survey 2 [Figure 9]. Analysis result in decreasing order of score range is shown in figure 10 for survey 1 and figure 11 for survey 2.

From common result of both analysis, based from the requirement and sample, it was shown that, in this research condition in terms of its sample and requirement, the clear relationship among image items which are event and car, give most influenced to the comprehensibility. For example, the cause of low comprehension level for 'fog' is due to the unclear relationship between the car and event, and light looks more obvious than the fog. For the improvement method, 'fog' needed to be expressed stronger in order to give influence to the car.

Regardless of, in both analyses, it was incomprehensible when the car subject in graphic symbol is unclear whether the subject is referred to driver or other subject in ahead. This point is needed to be aware during the graphic symbol design. From the result, it can be assumed that another method to clarify the relation among image items is its cause and consequences and /or motion of car. However, from the analysis result showed that there are minus score in degree of comprehension for the car motion. This is also means there is an error occurred due to few samples. Moreover, it can be understand that moving or stop referred to an event. During expressing combining image items, it was described by research of Matsuda et al. that the appropriateness of a direction is important [8]. For survey 2, it was cleared that other requirements are more important than display color. Hence, there is a need for comprehensible graphic symbols to readjust not only the color but also the image item and its composition.
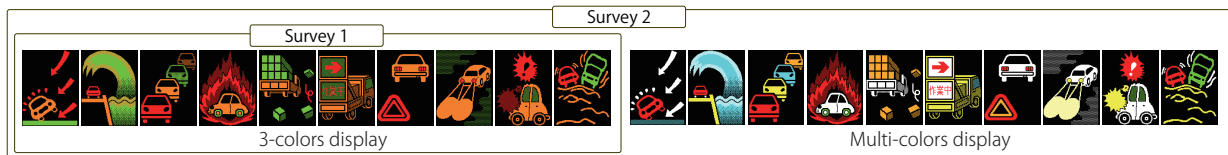
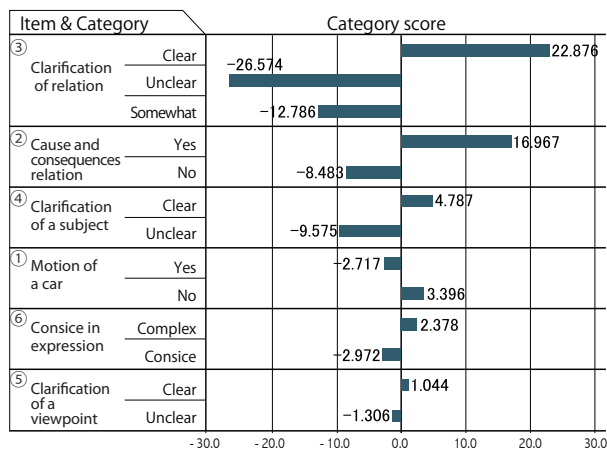

Figure 9. Samples for Quantification 1



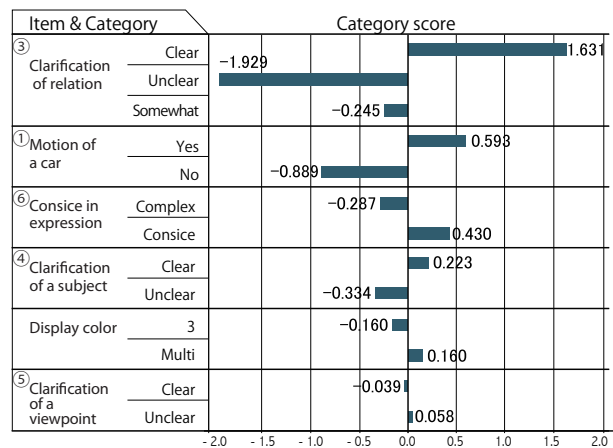Figure 10. Result of Quantification 1 (Survey1)



Figure 11. Result of Quantification 1 (Survey2)

## 5. Verification of Requirements

Based on the result by analysis of Quantification 1, 6 kinds of events for multi-color samples which need to be improved were prepared, as well as 'accident ahead', 'fog', 'fire occur ahead', 'falling object ahead', 'car trouble ahead', and 'earthquake'. Each sample expressed the relation between event and car.

Additionally, 5 samples from each event were chose. 1 existing sample was allocated in each event for the base comparison [Figure 12]. Then, the 6 samples from each event were evaluated by pair comparison method to verify the requirements for comprehensibility of graphic symbols.

### 5.1. Trial sample notes

There are 2 important requirements, first is 'clarification of relation' that clears the relation between event and car. The second is, the 'clarification of a subject', which it is incomprehensible when the car subject in graphic symbol is unclear such as the subject is referred to the driver or other subject ahead.

'Clarification of a relation' was expressed by the car motion, cause and consequences, and adjustment of the contrast size between the image items. 'Clarification of a subject' was expressed by adjusting the image items and color combination; and as for the car moving or stop is referred to the event, emotion, and the car direction. There were 2 kinds of samples which were modified existing items and re-designed items.

### 5.2. Evaluation of samples by pair comparison method

Each 6 event, consist of 5 trial samples with 1 existing graphic symbol that made the total of 6, were analyzed by pair comparison method to verify the requirements for comprehensibility of graphic symbols. The evaluation methods were arranging 2 kinds of samples horizontally and displaying simultaneously. At the same time, event name and detail meaning were displayed by text. Evaluation of which relation between text and samples is comprehensive was done in 5 Likert. For example the comparison between sample A and B was 'A is high', 'A is moderately high', 'neither of A or B', 'B is moderately high' and 'B is high'. Each event had 15 questions. Other experiment conditions were similar with the survey 1 and 2. Total of 13 driving license holders consist of 9 males and 4 female were selected as respondents.

The collected data were analyzed by AHP for the weight according to each respondent. The average of weight was analyzed by 2-way ANOVA, to observe the significance difference of an existing graphic symbol between trial graphic symbols. The 2-way was referred to the respondents and samples.

Result is shown on figure 13. There is increasing value towards the right in the map for the sample. The trial samples are more significance than existing graphic symbol when the p-value < 1%: ＊＊ , < 5%: ＊ , < 15%: △ in map.

### 5.3. Consideration about Verification of Requirements

Many of trial samples obtained higher evaluation than existing graphic symbol. Especially, it was proven that the importance of clarification between event and car which expressed the car motion in course and consequences relation. In addition, when the car motion is cleared whether it is moving or stop, the event detail is explained well. When the event detail is explained, the subject of car in graphic symbol will be cleared.

Above, the requirements in this study were verified by the trial samples. On the other hand, regarding the falling object, the significance difference was 30%, which means that there is a necessity on further idea study. In this trial sample, there was a high evaluation on graphic symbols that have detail expression on situation. However, when the visibility distance is making into consideration, more simple expression is needed.
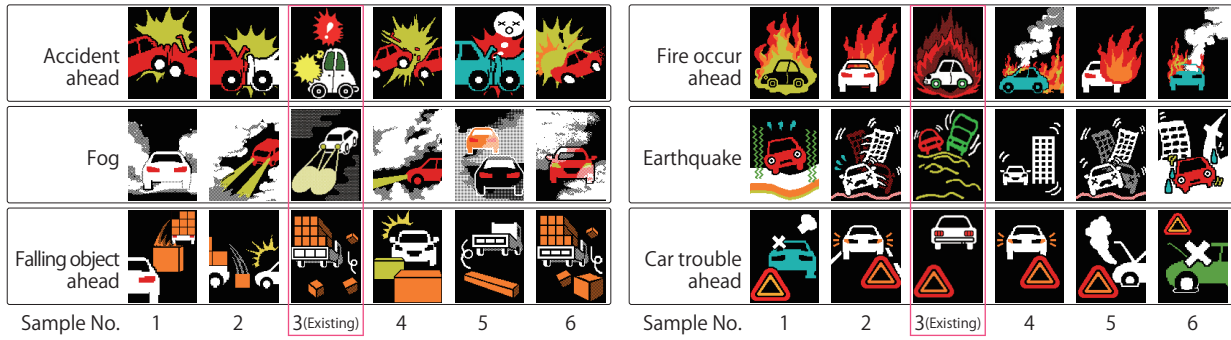
Figure 12 Samples for Pair Comparison Method



**✱✱**: p-value<1% **✱**: p-value<5% △: p-value<15%
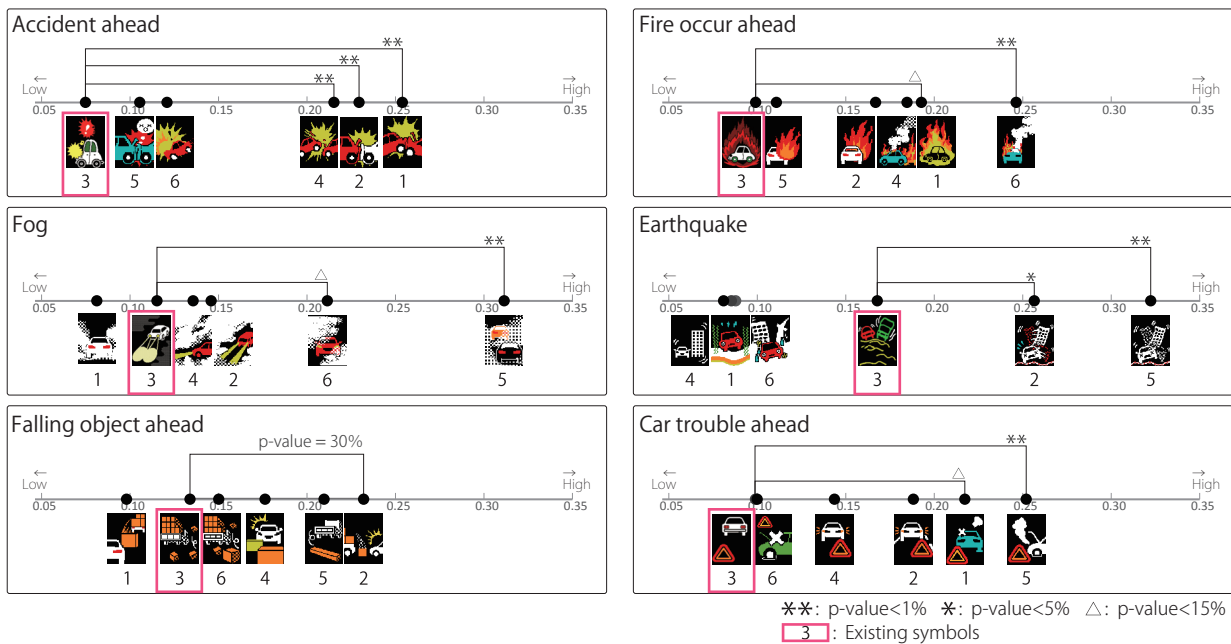3 : Existing symbols

Figure 13  Result of Pair Comparison Method with ANOVA

## 6. Conclusions and Future Studies

This study discussed comprehensibility of graphic symbols. It selected graphic symbols Japanese expressway information board as an example. The condition of existing graphic symbols was observed by the degree of comprehension and impression of comprehensibility. As the result, evaluation of impression indicated that white and reappearance color of multi-colors display are significant for comprehensibility. Both results of the observation indicated that most of graphic symbols using car picture required to be improved. Accordingly, requirements for comprehensibility of graphic symbols using car picture were extracted, influence level of the requirements was determined by analysis of Quantification 1. The requirements were verified by pair comparison method between trial samples and existing graphic symbols.

This study concluded that the main requirement is to present a clear relationship between event and car, in case of using the car picture as a part of graphic symbol. Therefore, expression of car motion in cause and consequences has effect. Moreover, it can be said that when the car motion is cleared whether it is moving or stop, the event detail is explained well; and when the event detail is explained, the subject of car in graphic symbol will be cleared.

In addition, for the future studies of graphic symbol design, it is needed to consider: distinguishability, visibility distance and easy to learn. On the other hand, it is need to survey on similar environment for the driving situation in terms of smaller sample size, short term of sample display time and motion view. In order to adopt symbol, it is required to measure time of comprehension as another index, and to verify by testing comprehension of graphic symbols.
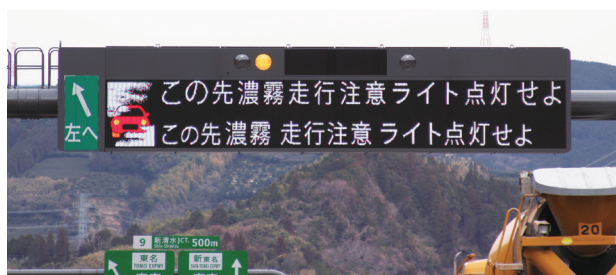
## Acknowledgement

Figure 13  Appearance of display test in Shin Tomei Expressway (before open to public)

## Annotation and Reference

[1] Expressway information board is installed to keep smooth and safety traffic. It displays the mutable information in order to respond to the road situation's changes.

[2] Takeo Iwata, Hiroki Wada (2000), *Advanced Variable Message Sign for Express Way,* Information Processing Society of Japan Research Report (ITS), no. 42, pp. 39-44

[3] The method of LED lighting display is beginning to change from 3-colors which are red, green and orange that made by a mix of red and green, to the Multi-colors which are red, green and blue with the regulation colors are 6 to 9. Furthermore, the data controlling system that transmits the picture (bitmap image) is proposed to replace conventional system. It is expected to increase the amount of information displayed and liberalization of composition. However, the comprehensible design is needed simultaneously.

[4] Yumiko Shimizu, Hiroyuki Akama (2006), *Evaluation for Relationships of Mobile Icons and Their Meanings: Their Understandable Conditions Depending on Reaction Times*, Journal of Japan Society of Kansei Engineering, vol.6, no. 3, pp. 3-10.

[5] Foundation for Promoting Personal Mobility and Ecological Transportation (2001), *Symbol Signs for Public Information*, pp. 38-41.

[6] Yutaka Nagami, Masahito Takizawa, Akira Kijima, Junichi Suzuki (2011), 高機能可変式道路情報板の判読性向上に関するデザイン検討 : *Design considerations on Improvement in the legibility of highly functional variable expressway information board*, The31st Japan Society of Traffic Engineers Presentation Collection of papers, vol. 31, no. 35, pp. 177-180.

[7] Moritarou Oono, Toshinobu Harada, Jun Munemori (2011), *Pictogram Design Support System Based on Information Analysis of 'Verbs'*, Bulletin of Japan Society for the Science of Design, vol. 58, no. 2, pp. 55-64.

[8] Motohiro Matsuda, Kazunari Ito, Martin J Durst, Koichi Hasida (2007), *A Rule Extraction Method for Arranging Pictogram Components*, The Database Society of Japan Letters 6 (1), pp. 165-168.