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Study on Traffic Sign Classification for Assessing Sign Comprehension

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Abstract—**Previous studies analyzed the relationship between drivers' personal characteristics and their comprehension of traffic signs directly, but neglected to test and control the influence of small class of traffic signs themselves. This error might cause the distortion of research results. So a comprehensive survey of drivers' comprehension of all warning signs was conducted in this paper. Average level of every warning sign comprehension was assessed. Warning signs were divided into four clusters using Hierarchical Cluster Analysis. The final classification scheme was determined based on significant difference test between clusters and homogeneity test within every cluster. Study results indicate that small class of traffic signs has certain influence on the level of traffic signs comprehension and it may inhibit the influence of drivers' personal characteristics. The traffic signs classification scheme can solve this problem effectively. This study will provide foundation for the study of comprehension and design of traffic signs.**

Keywords-level of sign comprehension; cluster analysis; drivers' personal characteristics; classification of traffic signs

I. INTRODUCTION

Traffic signs are to provide regulations, warnings and guidance information for road users in terms of color, shape, words, and symbols. They are one of indispensable parts that make up the traffic management system. With the rapid expansion of urban built-up area size and road network, the traffic sign system updates continuously and is to be more perfect. The success of playing the function of "Road Language" largely depended on whether drivers could comprehend signs correctly. When traffic signs provide information to road users, the extent of drivers' comprehension would differ because of different drivers' personal characteristics. Therefore, study on traffic signs comprehension was quite essential.

Topics and researches about drivers' conception of signs covered a wide range of aspect. But there were three main aspects, i.e. design factors of signs, divers' personal characteristics and study methodologies.

1) The effect of design factors on assessing signs comprehension

Drory A[1], Chapanis A[2], and Ellis J G[3] tested the effect of design factor, such as shapes, colors, words and symbols, on the drivers' perception. The results showed that colors and shapes played role in drivers' comprehension of signs. And they concluded that drivers' response time of symbolic signs was shorter than that of verbal signs.

2)The effect of drivers' personal characteristics on their comprehension of signs

John M. Mounce and H.G.Hawkins assessed how well motorists understood 46 traffic control devices including 28 signs. They analyzed the difference in percentage of correct understanding signs between different ages, sexes, races, speaking language, drivers education and driving experience briefly [4]. Hashim Al-Madani investigated the relationship between drivers' personal characteristics and their comprehension of 28 posted signs. In additional, he considered the effect of accident per experience ratio and nationality[5,6].

3) Study methodology

Susan T. Chrysler evaluated the effectiveness of different display methods to assess traffic sign comprehension. The data suggested that simply limiting the exposure time PowerPoint presentation was the most economic and reliable mythology[7]. Chen Yang from Chang'an University conducted experiment in real-road environment to test drivers' perception of specified signs. Results showed that for warning signs, drivers with more than 5000km estimated miles driven per year performed much better than ones with less than 5000km estimated miles. But for regulation signs there wFere no significant difference between the two classes of drivers[8].Wang Pei from Tsinghua University verified that different mental workload affected drivers' comprehension of signs in driving simulator[9].

Past researches assessing sign comprehension analyzed the relationship of characteristics and drivers' conception directly. These studies did not test homogeneity of signs and the influence of traffic signs themselves on drivers' comprehension. Accordingly the significant difference between levels of sign comprehension couldn't due to drivers' characteristics or small class of traffic signs themselves. A variable sign was a small class. For example, advisory speed warning sign was a small class. Uncertainty of analysis would cause distortion of final research results, even mistakes. However, studies on how to eliminate this error was still scarce. Based the absence of studying influence of traffic signs in previous studies, a scheme of classification of traffic signs was administrated to solve the error in this paper. First, a comprehensive investigation of traffic sign comprehension was developed. The average level of every sign comprehension was computed and described in a figure. Traffic signs included in the investigation were divided into 4 classifications using Cluster Analysis. The final result of warning signs classification was determined based on significant

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difference test between clusters and homogeneity test within every cluster. Therefore the effect of small class of traffic signs on drivers' comprehension of signs could be eliminated. For the signs with poor comprehension, a test of significant effect of divers' personal characteristics on traffic signs was analyzed.

II. SURVEY DATA COLLECTION AND ANALYSIS

A. *Traffic Survey program development*

1) The purpose of this survey

Purposes that were expected to be realized by investigating and studying were as following:

- to describe the distribution of different levels of warning signs comprehension;
- to establish classifications of warning signs;
- to analyze difference between drivers' understanding capacities in different personal characteristics.

2) Design of the questionnaire

In order to overall assessing warning sign comprehension, 54 warning signs were selected from the national standard of "Road traffic signs and markings" (GB5768-2009). The questionnaire involved a short–answer questions and a multiple choice comprehension test. The short–answer questions were designed to identify drivers' characteristics. The signs were illustrated in colors. The degree of drivers' comprehension was divided into three levels, i.e. understanding completely, uncertain and not-understanding completely. And the three levels of sign comprehension were remarked by number 1, 2 and 3. In this survey, every sign had three choices which were taken as the above three levels of sign comprehension. Respondents were required to select a response of every sign according to the first sensory.

3) Development of survey program

For the purpose of evaluate drivers' comprehension of urban warning signs, drivers with driving license were taken as survey objects. Car drivers were the main respondents. The survey was conducted around schools and large shopping malls at weekends for improving drivers' cooperation rate. And the diversity of sample could be guaranteed.

B. *Data Analysis*

The survey sample size was 105, and the effective sample was 101. Overall data distribution of different drivers' personal characteristics was shown in TABLE Ⅰ.

The sample size of survey and drivers' personal characteristics was sufficient to be representative for statistic analysis. The number of female drivers was small compared than male. Female drivers in these spots were too small difficult to investigate.

The level of sign comprehension was defined as the percentages of drivers who identified the warning sign correctly. On the basis of statistic analysis of 101 questionnaires, average comprehension level of every sign was computed. The result was described in figure 1. The comprehension levels were distributed from 14% to 100%. One-way Analysis of Various (ANOVA) was used for test each variable of divers' personal characteristics. However, there was no significant effect of these variables on sign comprehension except job variable. This result wasn't be compliance with the previous studies and disobeyed common sense. The further reason was explored for this queer result. Traffic signs themselves had different level of comprehension for factors, for example design factors. The distribution arrange of comprehension levels of warning signs was large. The maximum level was 100% while the minimum was 14%. Even the same respondent had different comprehension level for these signs. So the influence of small class of traffic signs themselves interfered drivers' personal characteristics working, and caused the deviation of the results. Therefore, traffic signs should be classified according to scientific methods to ensure no significant effect of traffic signs themselves on sign comprehension.

TABLE I. . SAMPLE SIZE OF DIFFERENT DRIVERS' PERSONAL CHARACTERISTICS

Personal Characteristic	Groups	Sample Size	Personal Characteristic	Groups	Sample Size
Sex	male	84	Job	Student	8
	female	17		Worker	7
Age (years)	18~24	10		Institution staffer	19
	25~34	36		Company staffer	39
	35~44	41		Service staffer	6
	>45	14		Self-employed	15
Monthly income (RMB)	<1500	8		others	7
	1500~2500	14	Years licensed	<1	5
	2500~3500	24		1~3	16
	3500~5500	19		3~5	16
	5500~8500	15		5~10	29
	8500~10000	11		>10	35
	>10000	10	Driving frequency (per week)	1	13
Educational background	Below senior high school	12		1~4	26
	Senior high school	27		>4	62
	Undergraduate college	45	Drive for job	Yes	28
	Higher than above	17		No	73

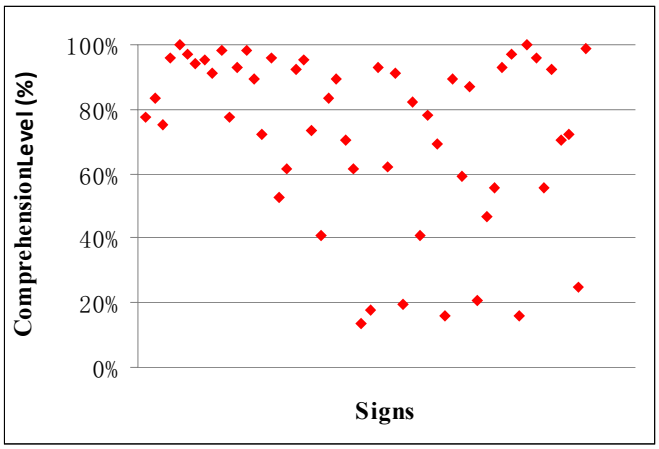

Figure 1. Distribution of comprehension level of warning sign

III. ⅢSCHEME DEVELOPMENT OF SIGN CLASSIFICATION

Traffic sign classifications were determined based on math methodology. It would ensure that every

classification was homogeneous, and the difference of small class of traffic signs was eliminated. The classification of signs would provide research basis for analyzing the influence of drivers' personal characteristics on their comprehension.

A. Unifying of design factors of traffic signs

Design factors of traffic signs included size, color, shape, symbol and so on. These factors had effect on sign comprehension [1,2,3]. So it was necessary to unify the design factors as much as possible. In this paper the symbolic warning signs were selected with black symbols or words on yellow background. And the shape was a upward-pointing equilateral triangle. Unified design factors of traffic signs reduced the interferer on drivers' comprehension of signs.

B. Cluster Analysis

Traffic signs were classified using Q- Cluster Analysis. Q- Cluster Analysis was a type of Hierarchical Cluster Analysis. The close degree of sample was measured by distance of variables and correlation coefficient. There was as much as similar within every cluster and different between clusters after classifying. In this study warning signs were clustered into four clusters according to the index of sign comprehension.

The statistic software SPSS17.0 was used for data processing. Select Analysis//Classify//Hierarchical Cluster in order. When opened the interface of Hierarchical Cluster, sign comprehension was selected as the Variable, and sign name was selected as Label Case. Sign names were clustered in the process. In the Cluster Method interface, Between-groups linkage was used and the distance of variables was measured by Squared Euclidean Distance. After setting related operations, run the software. And then the results of sign clustering displayed in the output.

The dendrogram using Average Linkage (Between Groups) was described in Figure 2. The results of sign clustering were shown in TABLE Ⅳ.

Warning signs were divided into four clusters, i.e. A, B, C and D which were stratified in down order. There were two purposes for signs classifying: 1) to know about the level of sign comprehension clearly; 2) to prepare research basis for studying influence of drivers' personal characteristics on understanding traffic signs. Drivers' personal characteristics included sex, age, job, monthly income, educational background, years licensed, driving frequency and drive for a job or not. A traffic sign was a small class in a sign cluster. For example, the cluster D had 7 small classes. To ensure small class did not affect sign comprehension significantly when analyzed the influence of these variables of personal characteristics, significant difference test between clusters and homogeneity test within every cluster were analyzed in this study.

C. Significant difference test between clusters

Because the data did not compliance Homogeneity of Variance Test, K-Independent Samples Nonparametric Test was selected. The methodologies of K-Independent Samples Test mainly included Median Test and Kruskal-Wallis Test. Significant differences test between clusters were tested by testing significant difference of median or mean rank. In this study Kruskal-Willis Method was selected and the result was shown in TABLE Ⅱ.

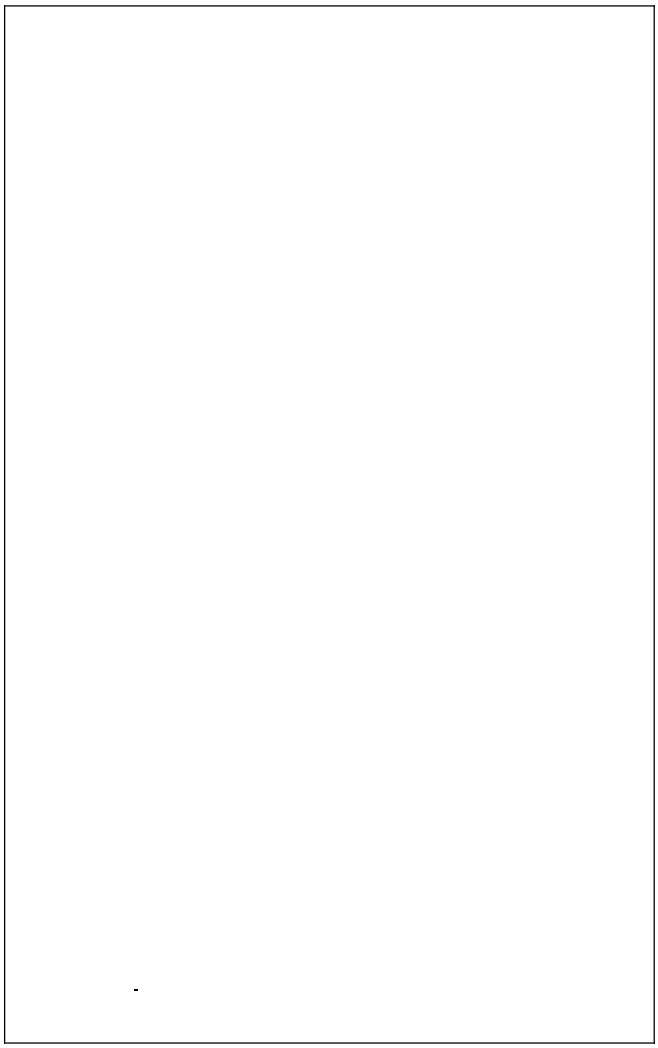

Figure 2. Dendrogram using Average Linkage (Between Groups)

TABLE II. RESULTS OF KRUAKAL-WALLIS TEST

Sign cluster	Mean Rank	df	Asymp. Significanc.	Clusters differed significantly or not
A:[0,0.4)	4.00	3	.000	Significantly
B:[0.4,0.7)	13.00			
C:[0.7,0.85)	24.50			
D:[0.85,1]	42.50			

Statistical analysis showed that concomitant probability P was 0.000 which was less than 0.05 at the significant level 0.05. So there were significant differences between the four clusters at 0.05 level.

D. Homogeneity test within-cluster

Homogeneity test is to test the rationality of combination and statistic analysis of study objects. And application of study of sign comprehension, Homogeneity test within-cluster was to test that whether there was significant difference between elements of every cluster, i.e. small class. In this paper the Cluster D with the worst

level of sign comprehension was test and other cluster could be analyzed according to test method of Cluster D.

The data of sign comprehension were combined effect of both drivers' personal characteristics and small class of every sign itself. So the data with-cluster D were tested using two-factor analysis of variance without repetition at 0.05 level. If concomitant probability P was more than 0.05, the small class of signs had no significant effect on sign comprehension. The statistic analysis function of EXCEL was used for data processing on the basis of Normal test and homogeneity test of variance. The results was collated as shown in TABLE Ⅲ.

TABLE III. TABLE 4 RESULTS OF HOMOGENEITY TEST WITHIN-CLUSTER CLASS

Source	df	F	P-value	F crit
Small class	4	3.741	0.115	6.388
Sex	1	0.874	0.403	7.709
Small class	6	1.328	0.295	2.661
Age	3	3.594	0.034	3.160
Small class	6	0.601	0.727	2.364
Job	6	9.502	0.000	2.364
Small class	6	1.265	0.298	2.364
Monthly income	6	3.486	0.008	2.364
Small class	6	1.467	0.245	2.661
Educational background	3	26.177	0.000	3.160
Small class	6	2.237	0.074	2.508
Years licensed	4	6.160	0.001	2.776
Small class	6	1.650	0.217	2.996
Driving frequency	2	4.821	0.029	3.885
Small class	6	0.361	0.880	4.284
Drive for a job	1	7.140	0.037	5.987

The significant influence could be concluded from Table 4. The concomitant probability P was more than 0.05 for the eight variables. There was no significant difference between small classes of signs at 0.05 level. The signs within cluster D were homogenous and could be analyzed when combined.

Meanwhile, clusters B, C and D were analyzed using the same method as cluster D. It was found that the clusters were homogenous except Cluster A. A further classification was carried out. However there was also significantly different between small class of signs, especially in the comprehension level of (0.95, 1]. It suggested that the influence of small class of signs on high comprehension was much more significant than that of drivers' personal characteristics. So it could not analyze the role of the personal characteristics on drivers' sign comprehension directly when warning signs were belong Cluster A.

It indicated some other results from Table 4. For the signs with low comprehension level, i.e. [0, 0.4], the sign comprehension was not affected by drivers' age. The variables of age, job, educational background, monthly income, years licensed, driving frequency and drive for a job played significant effect on drivers' comprehension of warning signs.

IV. CONCLUSIONS

The effect of traffic signs themselves on sign comprehension was to study based on a comprehensive survey and statistic analysis on data in this paper. Firstly, a comprehension survey about 54 warning signs was conducted. And the levels of warning sign comprehension were assessed on basis of statistic analysis. Secondly, the classifying standard of traffic signs was determined using math methodology. The study results indicated that Small class of traffic signs themselves had effects on sign comprehension. And it would interfere with the analysis of the influence of drivers' personal characteristics on sign comprehension. For eliminating this interferer, a scheme of sign classifying was administrated in this study. At first, warning signs were divided into four clusters using Q-Cluster Analysis. The four clusters were A , B, C and D with the comprehension level [0,0.4), [0.4,0.65), [0.65,0.85) and [0.85,1]. And then significant difference test between clusters and homogeneity test within every cluster were analyzed in this study. It could determine whether there was significant influence of small class of signs within every cluster on sign comprehension. The clusters were homogenous except Cluster A. So roles of divers' personal characteristics in understanding signs could be analyzed in cluster A, B and C. For signs with poor comprehension, age, job, educational background, monthly income, driving frequency, driving experience and whether professional drivers or not played significant effect on drivers' comprehension of traffic signs. These findings were important and provided study basis for studying sign comprehension.

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TABLE IV. RESULTS OF WARNING SIGNS CLUSTERING

Sign cluster	Sign name	Comprehension level	Sign cluster	Sign name	Comprehension level
A [85%,100%] 24 signs	Advisory speed	87%	B [65%, 85%） 13 signs	railway crossing with staff guard	69%
	Livestock	89%		Steep slop	70%
	Hump bridge	89%		Runaway truck ramp	70%
	Black spot ahead	89%		Wildlife	72%
	Road narrows both sides	91%		Iced pavement	72%
	Working zone ahead	91%		Ferry ahead	73%
	Village	92%		Offset side roads	75%
	Merge	92%		Cross road	77%
	Two-way traffic	93%		Narrow Bridge	77%
	Handicapped	93%		Slippery when wet	78%
	railway crossing without staff guard	93%		Fallen rocks	82%
	Reverse curve	94%		Y-symbol intersection	83%
	Winding curve	95%		Pavement may flood	83%
	Tunnel	95%	C [40%,65%） 10 signs	Bump	41%
	T-symbol intersection	96%		Cross wind area	41%
	Signal ahead	96%		Rough road	47%
	Dangerous ahead	96%		Dangerous road adjacent to mountain	52%
	Right turn	97%		Dip	55%
	Bicycle	97%		Open light close tunnel	55%
	Narrow roads from right	98%		Bypass from right side	59%
	Children	98%		Dam road	61%
	Fog area	99%		Continuous downhill	61%
	Circular intersection	100%		Bypass both sides	62%
	Slow down	100%	D [0, 40%） 7 signs	Railway crossing 50m ahead	18%
D	Fork symbol at Railway crossing	14%		Keep distance	20%
	Railway crossing 100m ahead	16%		Divided highways	21%
	Railway crossing 150m ahead	16%		Queuing ahead	25%